1ST ICSIID 2025

CONFERENCE PROCEEDINGS

1st International Conference on Sustainable Innovations and Infrastructure Development in Civil Engineering & Technology (1st ICSIID 2025) April 10-11, 2025

PROCEEDINGS BOOK

1st International Conference on Sustainable Innovations and Infrastructure Development in Civil Engineering & Technology (1st ICSIID 2025) April 10-11, 2025

Organized by:
Department of Civil Engineering, Mehran University of Engineering & Technology, SZAB Campus Khairpur Mir's, Sindh, Pakistan

In Collaboration with:
Sir Syed University of Engineering & Technology, Karachi **&**
Sindh Higher Education Commission

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PREFACE

On behalf of the Conference Committees of 1st International Conference on Sustainable Innovations and Infrastructure Development in Civil Engineering & Technology (1st ICSIID 2025), we are privileged to welcome you physically for this conference at Khairpur Mir's, Sindh, Pakistan. This conference is being organized by Department of Civil Engineering, Mehran University of Engineering and Technology, SZAB Campus Khairpur Mir's in collaboration with Sir Syed University of Engineering and Technology, Karachi and supported by Sindh Higher Education Commission (HEC), in which physical as well as online mode of participation will be witnessed from different countries of the world. This conference aims to provide a platform for young researchers, engineers, scientists, and academicians as well as industrial professionals and undergraduate / postgraduate students from the various universities to share and exchange knowledge, discuss findings and challenges in their respective fields of knowledge. The 1st ICSIID-25 will take place on 10th -11th April 2025, bringing together leading researchers, academics, professionals, and industry experts to discuss advancements in civil engineering and technology. This conference provides a national platform for exchanging ideas among researchers, students, faculty, scientists, engineers, and young professionals from academia, industry, and research organizations. The event will focus on pioneering technical work and cutting-edge research, addressing emerging trends in sustainable infrastructure development, innovative construction materials, intelligent systems in highway and traffic engineering, geotechnical solutions, urban planning, and environmental sustainability. The conference will feature international and national keynote speakers who will share their insights and expertise. International speakers include esteemed Professors and researchers from Malaysia, Thailand, Indonesia, and Oman, specializing in field of civil engineering, architecture, and sustainable infrastructure development. They will participate in discussions both in-person and online, contributing to the exchange of innovative ideas and advancements in the field. Similarly, national speakers from leading universities and research institutions in Pakistan will bring their expertise in structural engineering, urban planning, geotechnical studies, and sustainable construction. Their contributions will enhance discussions on infrastructure resilience, smart engineering solutions, and the future of civil engineering in the region. We acknowledge the support and cooperation of our esteemed partners in making this conference a success. We would like to acknowledge the conference organizing committee, technical review committee, printing & publication committee, and funding and sponsorship committee and registration committee for their time and support. We would like to thank all authors who have submitted their papers to make this conference possible. Our sincere thanks go to members of conference team along with the officers, staff and student volunteers for their tireless efforts and continuous support.

Dr. Sajjad Ali Mangi
(Conference Chair)
Email: Sajjad.nec@muetkhp.edu.pk

Acknowledgment

The organizing committee of ICSIID 2025 sincerely acknowledges the generous support and collaboration of our esteemed sponsors and contributors, whose valuable participation played a vital role in the success of the event.

We are grateful for the sponsorship and encouragement extended by Sun Tang Technology Pvt. Ltd. Khairpur, Arsalan Construction Company, Sindh Rural Support Organization (SRSO), Mr. Abdul Sattar Arbani (Builder), Engr. Mohammad Faisal Shaikh Construction Company, and ALI Construction Company.

The organizing committee extends heartfelt appreciation for their contribution and presence, which added value to the conference.

We would also like to express our sincere gratitude to all National and International Keynote Speakers, Authors, Participants, Session Chairs and Co-Chairs, Organizers, and Teacher Coordinators for their enthusiastic involvement and support, which made ICSIID 2025 a distinguished and impactful event.

Special thanks are due to the tireless efforts and dedication of the entire conference organizing committee, whose hard work ensured the event's successful execution.

CONFERENCE COMMITTEES

1. Steering Committee				
S. No.	**Name**	**Designation**	**University**	**Role**
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S. No.	**Name**	**Designation**	**University**	**Role**
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4	Mr. Zahid Hussain Matilo	Assistant	MUET SZAB	Secretary
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S. No.	**Name**	**Designation**	**University**	**Role**
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5	Engr. Faheem Ahmed Soomro	Executive Engineer	KMC	Member
6	Mr. Zahid Hussain Matilo	Assistant	MUET SZAB	Member
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S. No.	**Name**	**Designation**	**Organization**	**Role**
1	Mr. Abdul Rasheed Phulpoto	Deputy Director ICPC	MUET SZAB	Convener
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3	Mr. Abdul Sami Shaikh (Video Conf. Hall)	Assistant	MUET SZAB	Member
4	Mr. Kazim Ali Shah (SIREN)	Jr. Clerk	MUET SZAB	Member
6. Boarding, Lodging & Transport Committee				
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3	Engr. Abdul Majid	Lecturer	MUET SZAB	Member
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5	Engr. Naeem Abro	Incharge Transport	MUET SZAB	Member
6	Mr. Zahid Hussain Matilo	CCPO	MUET SZAB	Member
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10	Volunteers	Students	Civil Students	Member

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S. No.	**Name**	**Designation**	**University**	**Role**
1	Dr. Abdul Qayoom Memon	Assistant Professor	MUET SZAB	Convener
2	Dr. Rabia Soomro	Assistant Professor	MUET SZAB	Member
3	Dr. Hemu Karira	Assistant Professor	MUET SZAB	Member
4	Engr. Dhanesh Kumar	Lecturer	MUET SZAB	Member

8. Conference Hall Maintenance Committee				
S. No.	**Name**	**Designation**	**University**	**Role**
1	Mr. M Rakhial Bhutto	Project Director	MUET SZAB	Member
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9. Conference Hall Management Committee				
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3	Mr. Wazeer Hussain	Lab. Engineer	MUET SZAB	Member
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10. Technical Review Committee				
S. No.	**Name**	**Designation**	**Organization**	**Role**
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6	Engr. Sheeraz Ahmed Rahu	Lecturer	MUET SZAB	Member
7	Dr. Asim Ali Abro	Assistant Professor	BBSUTSD	Member
8	Prof. Dr. Mohd Haziman Wan Ibrahim	Professor	UTHM Malaysia	Member

9	Prof. Dr. M. Ikhsan Setiawan	Professor	NU Indonesia	Member
10	Dr. Lapyote Prasittisopin	Associate Professor	Thailand	Member
11	Dr. Naveed Anwar	Adjunct Faculty	AIT Thailand	Member

11. Security and Vigilance Committee

S. No.	Name	Designation	University	Role
1	Mr. Nadeem Ahmed Sarhandi	Security Officer	MUET SZAB	Convener
2	Mr. Rasheed Ahmed Phulpoto			

12. Field Visit Committee

S. No.	Name	Designation	University	Role
1	Dr. Mujeeb Iqbal Soomro	Assistant Professor	MUET SZAB	Convener
2	Mr. Zahid Hussain Matilo	Assistant	MUET SZAB	Member

13. Registration Committee

S. No.	Name	Designation	University	Role
1	Dr. Muhammad Jaffar	Associate Professor	MUET SZAB	Convener
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10	Volunteers	Students	Civil Students	Member

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15. Media & Photography Committee

S. No.	Name	Designation	University	Role
1	Mr. Saleem Ahmed Soomro	PRO	MUET SZAB	Convener
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3	Dr. Hemu Karira	Assistant Professor	MUET SZAB	Member
4	Engr. Naveed Ali Channa	Lecturer	MUET SZAB	Member
5	Mr. Abdul Qayoom Khaskhali	Lab. Technician	MUET SZAB	Member
6	Mr. Amir Soomro	ORIC	MUET SZAB	Member
7	Mr. Zahid Hussain Matilo	Assistant	MUET SZAB	Member
9	Volunteer	Volunteer	Civil Students	Member

INTERNATIONAL KEYNOTE SPEAKERS

1st ICSIID/KHP/01

Prof. Dr. Mohd Haziman Wan Ibrahim is a Professor in Faculty of Civil Engineering and Built Environment at Universiti Tun Hussein Onn Malaysia. As a faculty member, he served as a Head of Panel from 2006 – 2008 and 2011 – 2012, Head of Department for Department of Structure and Material Engineering from 2012-2014, Deputy Dean (Research and Development) from 2015-2016 and Deputy Dean (Academic and International) 2017 – 2020. Besides, he also served as a Vice President for Concrete Society Malaysia (CSM) from 2016-2018, President CSM from 2018 – 2020 and Fellow CSM from 2021 - present. He is an active researcher specialized in Concrete Technology, Construction Materials and Brickwork Engineering. Currently, he has published 3 books and more than 150 papers or articles in journal, proceeding and book chapter including 140 articles indexed in Scopus and WOS with H-index of 25.

1st ICSIID/KHP/02

Prof. Madya Ir. Ts. Dr. Riduan Bin Yunus is an Associate Professor in Civil Engineering at Universiti Tun Hussein Onn Malaysia (UTHM), specializing in Environmentally Sustainable Construction. With a Ph.D. in Construction Management from Queensland University of Technology, he focuses on sustainable construction, waste management, and lean construction practices. Currently serving as Deputy Director (Commercialization) at UTHM's Innovation and Commercialization Center, he has led numerous research projects, including studies on construction waste and net-zero energy buildings. Dr. Riduan is a registered Professional Engineer with the Board of Engineers Malaysia (BEM) and an Asean Chartered Professional Engineer, actively contributing to sustainable construction frameworks and academic development.

1st ICSIID/KHP/03

Dr. Lapyote Prasittisopin is an Assistant Professor in Green Architectural Technology at Chulalongkorn University, Thailand, with expertise in building materials, digital construction, materiality, sustainability, and architectural engineering. He currently serves as the Assistant Dean for Research Affairs at the Faculty of Architecture and is the Director of the Center of Excellence on Green Tech in Architecture. Additionally, he is an arbitrator with the Thailand Arbitration Center (THAC) and a member of the editorial board for Discover Concrete and Cement (Springer Nature). Dr. Prasittisopin holds a Ph.D. in Civil Engineering (Structural Material) and an M.S. in Material Science (Polymer) from Oregon State University, USA, along with a B.Eng. in Chemical Engineering from Chulalongkorn University, Thailand, and an LL.B. in Law from Sukhothai Thammathirat Open University, Thailand. His professional credentials include passing the Chartered Financial Analyst (CFA) Level 1 exam and certifications in leadership development, innovative organization assessment, LEED Green Associate accreditation, and Six Sigma methodology.

1st ICSIID/KHP/04

Dr. Muhammad Ikhsan Setiawan received his Bachelor of Civil Engineering (2002) from Universitas Merdeka, Malang, Indonesia, and Master of Civil Engineering (2005) from Universitas Indonesia before pursuing Ph.D. (Civil Engineering) at Universitas Tarumanagara, Indonesia (2010). He currently an Assistant Professor at Faculty of Civil Engineering, Narotama University, Indonesia and registered as Engineer Expert Certified. He currently leads a research team in Sustainable and Digital in Transportation, Tourism and Regional Economic, grant from Ministry of Education, Indonesia. His research interests include Smart City and Sustainability. He is also a Chairman of WORLDCONFERENCE.ID, member of IEEE, editors, and reviewers some Journal, until now as Vice Rector of Narotama University, Indonesia.

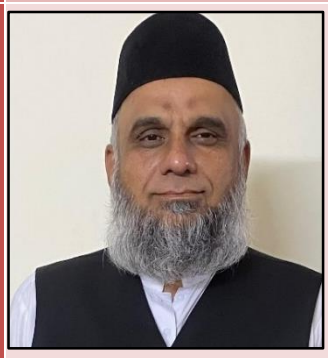
1st ICSIID/KHP/05

Dr. Tahir Mehmood is an Associate Professor at COMSATS University Islamabad, Pakistan, and a faculty member at Sultan Qaboos University, Oman, specializing in structural dynamics and earthquake engineering. He holds a Ph.D. in Civil Engineering from the Asian Institute of Technology, Thailand, where his research focused on the nonlinear seismic response of high-rise RC wall structures. With extensive academic and industry experience, he has worked as a Project Engineer at AIT Solutions, Bangkok, conducting seismic risk assessments and retrofitting of high-rise buildings. His expertise includes performance-based seismic evaluation, nonlinear analysis, and vulnerability assessment of structures. Dr. Mehmood has been awarded prestigious fellowships, including the Higher Education Commission of Pakistan Scholarship for both his master's and Ph.D. studies, and has received the Seal of Excellence in Marie Skłodowska-Curie Actions (MSCA-2019). He has led multiple funded research projects, supervised graduate students in advanced structural analysis, and contributed significantly to the field through teaching, research, and international collaborations.

NATIONAL KEYNOTE SPEAKERS

1st ICSIID/KHP/06		**Prof. Dr. Abdul Jabbar Sangi** is an Associate Professor of Civil Engineering at NED University of Engineering and Technology, Pakistan, with expertise in numerical modelling and dynamic analysis of reinforced concrete structures. He holds a Ph.D. in Civil Engineering from Heriot-Watt University, Edinburgh, and a Master's in Civil Engineering from NED University, Karachi. His research focuses on the behaviour of reinforced concrete structures under transient and impact loading, earthquake engineering, and nonlinear finite element analysis. With a strong academic and research background, Dr. Sangi actively contributes to advancements in structural engineering through teaching, research, and numerical modelling of complex structural systems.
1st ICSIID/KHP/07		**Prof. Dr. Abdul Sami Qureshi** is a Professor in the Civil Engineering Department at Sir Syed University of Engineering and Technology. Former Pro-Vice Chancellor Mehran University of Engineering and Technology (MUET), SZAB Campus Khairpur Mirs, Sindh. Specializing in transportation engineering, highway and traffic engineering, highway materials, and highway design. His expertise extends to Quality Management Systems (QMS), ensuring the development of efficient and sustainable transportation infrastructure. With extensive academic and research experience, Dr. Qureshi actively contributes to advancements in highway engineering through teaching, research, and practical applications in transportation systems.
1st ICSIID/KHP/08		**Prof. Dr. Khalid Khan** is the Founder of KP Science & Technology System, Peshawar, with a distinguished career in research, innovation, and technological advancements. With extensive expertise in science and technology, he has played a pivotal role in promoting research-driven solutions and sustainable development initiatives. Through his leadership, Dr. Khan has contributed to various scientific and engineering advancements, fostering innovation in academia and industry.
1st ICSIID/KHP/09		**Dr. Adnan Nawaz** is an Associate Professor and Chairperson of the Department of Civil Engineering at COMSATS University Islamabad, Wah Campus. With a distinguished academic background, including a Doctor of Engineering from the Asian Institute of Technology, Thailand, Dr. Nawaz has over a decade of experience in teaching, research, and consultancy. His expertise lies in structural engineering, sustainable construction materials, and advanced concrete technology, with a strong focus on incorporating waste and recycled materials into cement composites. Dr. Nawaz has published extensively in high-impact journals, collaborated on national and international research projects, and secured significant research funding. As a dedicated educator and mentor, he has supervised numerous graduate students and actively contributed to education.

1st ICSIID/KHP/10		**Dr. Hassan Ashraf** is an Assistant Professor in the Civil Engineering Department at COMSATS University Islamabad, Wah Campus, with expertise in construction project management, conflict management, alternative dispute resolution, and interface management. With a strong academic and research background, he focuses on optimizing project efficiency, resolving disputes in construction projects, and enhancing management strategies. His contributions to the field support sustainable and effective construction practices through research, teaching, and industry collaboration.
1st ICSIID/KHP/11		**Dr. Irfan Ahmad Rana** is the Head of the Department and an Assistant Professor in the Department of Urban and Regional Planning, with over 13 years of experience as a professional urban planner. He holds a Ph.D. in Regional and Rural Development Planning from the Asian Institute of Technology (AIT), Thailand, and is a registered member of the Pakistan Council of Architects and Town Planners (PCATP) and the Institute of Planners, Pakistan (IPP). Additionally, he is affiliated as a Young Scientist with Integrated Research on Disaster Risk (IRDR), under the United Nations Office for Disaster Risk Reduction (UNDRR). His research focuses on climate risks and vulnerabilities in urban and rural areas, covering topics such as urban resilience, climate change adaptation, disaster risk reduction, climate justice, and risk management related to heat and flooding. He has conducted extensive studies on climate risk perceptions, preparedness, and adaptation planning, utilizing quantitative and artificial intelligence methods for assessing exposure, capacities, and inequalities.
1st ICSIID/KHP/12		**Dr. Muhammad Usman** is a tenured Associate Professor and Head of Structures at the NUST Institute of Civil Engineering (NICE-SCEE), NUST, Islamabad, where he also serves as the OBE Coordinator and Official OBE Trainer at PDC-NUST. He holds a Ph.D. in Civil Engineering from the Korea Advanced Institute of Science and Technology (KAIST), Republic of Korea, with research expertise in 3D concrete printing, machine learning, earthquake engineering, vibration control, sustainable construction materials, and impact loading. With over 60 journal publications, including 40+ ISI-indexed papers and 20 international conference papers, Dr. Usman has a cumulative impact factor exceeding 220+, with over 1,360 citations, an H-index of 19, and an i10-index of 29. He actively contributes to academic publishing as an Academic Editor for "PLOS ONE" and "Advances in Civil Engineering," Managing Editor & Section Editor for the "NUST Journal of Engineering Sciences," and Guest Editor for MDPI journals including "Smart Cities" and "International Journal of Distributed Sensor Networks." Dr. Usman has led multiple funded research projects, including the development of Magneto-Rheological Elastomer (MRE)-based seismic isolation systems and sustainable 3D concrete printing technology.

1st ICSIID/KHP/13		**Engr. Prof. Dr. Manthar Ali Keerio** is Dean and Professor at BBSUTSD, Khairpur Mirs, Sindh, Pakistan, specializing in materials, fiber-reinforced concrete, self-compacting and geopolymer concrete. He holds a Ph.D. from QUEST, Nawabshah, an M.E. from MUET, and a B.E. (Silver Medalist) from QUEST. With 20+ years of academic and field experience, he previously worked as an Executive Engineer at WAPDA, contributing to RBOD and Neelum-Jhelum Hydro-Power projects. Dr. Keerio has 43+ journal publications, 25+ conference papers, and has supervised two Ph.D. graduates (two ongoing) and 12+ master's students.
1st ICSIID/KHP/14		**Dr. Muhammad Aslam Bhutto** is a highly accomplished civil engineer and academic with a Ph.D. in Structural Engineering from Heriot-Watt University, UK. Currently serving as an Associate Professor at TIEST (NEDUET) Mithi, he specializes in strengthening steel structures using FRP composites and researching innovative construction materials like bio-concrete and seawater-concrete. With over two decades of experience, he has held various academic and administrative roles, including Assistant Professor at NEDUET Karachi and Deputy Registrar. Dr. Bhutto is an HEC-approved PhD supervisor, has secured significant research grants, and published extensively in reputed journals. He is also actively involved in quality assurance, accreditation, and training initiatives, contributing to the advancement of engineering education and construction practices in Pakistan.
1st ICSIID/KHP/15		**Dr. Hamid Arshad** is an Assistant Professor and Head of the Department of City and Regional Planning at the University of Management and Technology, Lahore, Pakistan. He holds a Ph.D. in Regional Development Planning from the Asian Institute of Technology (AIT), Thailand, and has extensive experience in urban planning, housing strategies, and climate resilience. He has worked with international organizations, including the United Nations High Commissioner for Refugees (UNHCR) and the Erasmus Mundus Researchers Group, and has led major urban development projects such as the Punjab Affordable Housing Program and Naya Pakistan Housing Project. His research focuses on sustainable urban planning, spatial analysis, and environmental risk management, with publications in high-impact international journals. Dr. Arshad has also contributed to land-use planning, disaster risk reduction, and sustainable infrastructure development in Pakistan, Thailand, and Spain.

1st ICSIID/KHP/84		**Dr. Muhammad Usman Hassan** has 18 years of experience in construction planning, bid management, OHS, and project management in Pakistan, Saudi Arabia, and Turkey. He is ISO14001 lead auditor and has a number of certification in Quality, Occupational health safety, social accountability and environment. He was the team lead for OHS at Telenor Pakistan before becoming the OHS manager for occupational health and safety at Ericsson Saudia Arabia and Pakistan. He is currently serving as Assistant Professor and Director of Construction Management and Safety Research center at the School of Civil and Environmental Engineering, National University of Sciences and Technology (NUST) in Islamabad, Pakistan. He has a PhD in Construction Engineering and Management (CE&M) and MS in Construction Engineering and Management (CE&M), and BE in Civil engineering from NUST, Islamabad. He co-created a technology startup in Turkey that focused on using AI and sensor networks for construction and building information acquisition. His current area of research currently encompasses construction automation, machine learning, and robotics.
1st ICSIID/KHP/85		**Dr. Zafar Ahmed Siddiqui** is a distinguished academician and professional speaker, serving as Director at ORIC and overseeing the Business Incubation Center at a leading university. He is a mentor and trainer for UNDP and NBDP-SMEDA and serves as Deputy Convener of PEC's Innovation and Entrepreneurship Committee. As an expert reviewer for World Bank-HEC programs, he has evaluated research and technology transfer initiatives. He has been a keynote speaker, panelist, and trainer at numerous universities, corporate groups, NGOs, and government institutions. His diverse career includes leadership roles in industry and service in the Pakistan Air Force.

KEYNOTES

INTERNATIONAL KEYNOTE SPEAKERS			
S.No.	**ABSTRACT ID**	**AUTHOR / PRESENTER**	**TITLE OF ABSTRACT**
1.	1st ICSIID//KHP/01	Prof. Dr Mohd Haziman Wan Ibrahim	EVALUATING THE PERFORMANCE OF FIRED CLAY BRICK WALL IN AGGRESSIVE ENVIRONMENT AND THE POTENTIAL OF INTERLOCKING COMPRESSED EARTH BLOCK AS SUSTAINABLE SOLUTION
2.	1st ICSIID//KHP/02	Dr. Riduan Yunus	REVOLUTIONISING THE CONSTRUCTION INDUSTRY: THE SYNERGY OF CIRCULAR ECONOMY AND INDUSTRIALISED BUILDING SYSTEM (IBS)
3.	1st ICSIID//KHP/03	Dr. Lapyote Prasittisopin	DEVELOPMENT OF COOLING BRICKS USING POWERPLANT BYPRODUCTS FOR IN-FIELD THERMAL COMFORT AND URBAN COOLING SIMULATION
4.	1st ICSIID//KHP/04	Dr. Muhammad Ikhsan Setiawan	A DUAL INDONESIA INSTITUTIONAL APPROACH TO MARITIME SUSTAINABILITY: ENVIRONMENTAL INITIATIVES BY PELINDO AND PERTAMINA
5.	1st ICSIID//KHP/05	Dr. Tahir Mehmood	SUSTAINABLE ENGINEERING: BUILDING A

			RESILIENT AND GREEN FUTURE
NATIONAL KEYNOTE SPEAKERS			
S.No.	**ABSTRACT ID**	**AUTHOR / PRESENTER**	**TITLE OF ABSTRACT**
6.	1st ICSIID//KHP/06	Prof. Dr. Abdul Jabbar Sangi	THERMAL BLOCK: A SUSTAINABLE SOLUTION FOR WALL INSULATION
7.	1st ICSIID//KHP/07	Prof. Dr. Abdul Sami Qureshi	CHALLENGES, AND FUTURE PATHWAYS FOR GREEN MOBILITY IN KARACHI
8.	1st ICSIID//KHP/08	Prof. Dr. Khalid Khan	WATER-SMART INFRASTRUCTURE: INNOVATIONS IN WATER CONSERVATION, MANAGEMENT, AND RECYCLING IN CIVIL ENGINEERING
9.	1st ICSIID//KHP/09	Dr. Adnan Nawaz	INNOVATIVE USE OF INDUSTRIAL STEEL SCALE WASTE IN HIGH-PERFORMANCE CONCRETE FOR SUSTAINABLE CONSTRUCTION
10.	1st ICSIID//KHP/10	Dr. Hassan Ashraf	DOES SAFETY VOICE INFLUENCE WORKERS' SYSTEMATIC PROBLEM SOLVING: EXAMINING THE MEDIATING ROLE OF PERCEIVED SAFETY KNOWLEDGE ARTICULATION OF WORKERS
11.	1st ICSIID//KHP/11	Dr. Irfan Ahmad Rana	THE URBAN ADAPTATION PLANNING: A TRANSFORMATIVE APPROACH TO BUILDING SUSTAINABLE AND RESILIENT CITIES FOR THE FUTURE
12.	1st ICSIID//KHP/12	Dr. Muhammad Usman	3D CONCRETE PRINTING: CHALLENGES AND OPPORTUNITIES FOR CONSTRUCTION INDUSTRY IN PAKISTAN
13.	1st ICSIID//KHP/13	Engr. Prof. Dr. Manthar Ali Keerio	AN INVESTIGATION ON USE OF LOCAL METAKAOLIN AS A CEMENT SUBSTITUTION MATERIAL: A SUSTAINABLE CONSTRUCTION MATERIAL
14.	1st ICSIID//KHP/14	Dr. Muhammad Aslam Bhutto	FINITE ELEMENT ANALYSIS OF STEEL PLATE GIRDERS: STRUCTURAL BEHAVIOR, FAILURE MECHANISMS, AND DESIGN OPTIMIZATION
15.	1st ICSIID//KHP/15	Dr. Hamid Arshad	REDEFINING INFRASTRUCTURE STANDARDS FOR SUSTAINABLE AND AFFORDABLE HOUSING: AN INTEGRATED APPROACH TO URBAN PLANNING FOR DEVELOPING CITIES
16.	1st ICSIID//KHP/84	Dr. Muhammad Usman Hassan	AI IN CIVIL ENGINEERING: DISRUPTING STAGNATION THROUGH INDIGENOUS INNOVATION
17.	1st ICSIID//KHP/85	Dr. Zafar Ahmed Siddiqui	THE ROLE OF ENGINEERING COMMUNITY-BASED ADAPTATION TO CLIMATE CHANGE: PROTECTING INFRASTRUCTURE OF URBAN SINDH IN FUTURE

ICSIID-2025 Conference Program

📍 *MUET SZAB Campus, Khairpur Mir's*
🗓 **10–11 April 2025**

🔷 **DAY 1 – Thursday, 10 April 2025**
🟫 **Opening Ceremony**
🕘 **Time: 08:30 AM – 11:30 AM** 📍 **Venue: Main Auditorium**

Time	Activity
08:30 AM	Registration
09:30 AM	Guests to be seated
09:40 AM	Recitation from the Holy Quran
09:45 AM	National Anthem
09:50 AM	Welcome Note & Conference Brief – *Conference Chair, MUET SZAB*
10:00 AM	Guest of Honor Speech
10:15 AM	Keynote Speech – *Prof. Dr. Mohd Haziman Wan Ibrahim (Malaysia)*
10:30 AM	Keynote Speech – *Dr. Lapyote Prasittisopin (Thailand)*
10:45 AM	Souvenir Distribution
11:00 AM	Speech – *Pro-Vice Chancellor, MUET SZAB Campus*
11:10 AM	Chief Guest Speech
11:20 AM	Vote of Thanks – *Conference Secretary*
11:30 AM	Hi-Tea Break

Parallel Technical Sessions – Morning
Time: 12:00 PM – 02:30 PM

Session	Venue	Chair	Co-Chair	Facilitators
Session I	Main Auditorium	Prof. Dr. Mohd Haziman Wan Ibrahim	Dr. Sajjad Ali Mangi	Mr. Yasir Ali Solangi
Session II	Video Conference Hall	Dr. Lapyote Prasittisopin	Dr. M. Jaffar Memon	Mr. Abdul Sami Shaikh, Engr. Naveed Channa
Session III	SIREN Lab	Dr. Asim Abro	Dr. Abdul Qayoom	Engr. Sheeraz, Kazim Shah

Note: These sessions include keynote presentations and technical talks on sustainability, materials, structural innovations, AI applications, and urban resilience.

Lunch & Prayer Break
02:30 PM – 03:30 PM
Parallel Technical Sessions – Afternoon
Time: 03:30 PM – 04:40 PM

Session	Venue	Chair	Co-Chair	Facilitators
Session IV	Main Auditorium	Prof. Dr. Abdul Jabbar Sangi	Dr. Asim Abro	Mr. Yasir Ali Solangi
Session V	Video Conference Hall	Dr. Zafar Ahmed Siddiqui	Dr. Ghulam Shabir	Mr. Abdul Sami Shaikh, Engr. Naveed Channa
Session VI	SIREN Lab	Dr. Muhammad Usman Hassan	Dr. Abdul Qayoom	Engr. Sheeraz, Kazim Shah

Gala Night
09:00 PM – 12:00 AM
Venue: Main Auditorium
Event: *Dinner & Cultural Musical Program*

DAY 2 – Friday, 11 April 2025

Parallel Technical Sessions – Morning

Time: 08:30 AM – 10:40 AM

Session	Venue	Chair	Co-Chair	Facilitators
Session VII	Main Auditorium	Dr. Hamid Arshad	Dr. M. Aslam Bhutto	Mr. Yasir Ali Solangi
Session VIII	Video Conference Hall	Prof. Dr. Kanya Lal	Dr. Rabia Soomro	Mr. Abdul Sami Shaikh, Engr. Naveed Channa
Session IX	SIREN Lab	Dr. Zafar Ahmed Siddiqui	Dr. Abdul Qayoom	Engr. Sheeraz, Kazim Shah

Closing Ceremony

Time: 11:00 AM – 01:00 PM

Venue: Main Auditorium

Time	Activity
11:00 AM	Guests to be seated
11:20 AM	Recitation from the Holy Quran
11:25 AM	Conference Recommendations – *Director Academics, MUET SZAB Campus*
11:45 AM	Guest of Honor Speech
12:00 PM	Souvenir Distribution
12:30 PM	Chief Guest Speech
12:45 PM	Vote of Thanks – *Conference Secretary*

Lunch & Prayer

01:00 PM – 03:00 PM

End of Conference

Keynotes

Ref: 1st ICSIID//KHP/01

EVALUATING THE PERFORMANCE OF FIRED CLAY BRICK WALL IN AGGRESSIVE ENVIRONMENT AND THE POTENTIAL OF INTERLOCKING COMPRESSED EARTH BLOCK AS SUSTAINABLE SOLUTION

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ABSTRACT: The influence of aggressive environmental exposures on the performance of masonry systems has been investigated. The investigation involved the measurement of deformation and strength of single leaf masonry walls which were built from fired-clay brick in conjunction with designation (iii) mortar with proportions of 1: 1: 6 (OPC: lime: sand). After being constructed, the masonry walls were cured under polythene sheet for 14 days in a controlled environment room with temperature of 20±5ºC and 80±5% relative humidity. They were then exposed to sodium sulphate and sodium chloride solutions at concentrations of 5%, 10% and 15% respectively. The deformation and strength of the brick walls was determined at the ages of 28, 56, and 180 days. In addition, the properties of companion control walls, brick units and mortar were also assessed so that the effects of the aggressive exposure conditions could be quantified. As a result, after the period of exposure to the soluble salt conditions, reduction in strength of masonry wall were observed in particular for the case of sulphate exposures. These are mainly associated with the formation of ettringite crystals in the mortar, inducing expansion, cracking and disintegration of the mortar which led to the disintegration of the masonry walls. This finding also revealed that the main weakness of brickwork when exposed to aggressive environments was due to the weakness of the mortar. Therefore, interlocking blocks can be an alternative for sustainable construction because they are mortarless and can reduce the risk when exposed to aggressive environments.

KEYWORDS: Masonry performance, aggressive environments, sodium sulphate, sodium chloride, mortar degradation.

Ref: 1st ICSIID//KHP/02

REVOLUTIONISING THE CONSTRUCTION INDUSTRY: THE SYNERGY OF CIRCULAR ECONOMY AND INDUSTRIALISED BUILDING SYSTEM (IBS)

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ABSTRACT: The construction industry has a significant environmental impact, contributing to high carbon emissions, excessive material waste, and resource depletion. Industrialised Building Systems (IBS) present a sustainable alternative by incorporating prefabrication, mechanisation, automation, and robotics to improve efficiency and reduce environmental harm. This paper introduces the various levels of industrialisation to provide a comprehensive understanding of IBS and its potential in advancing sustainable construction. The study explores the integration of a circular economy framework within IBS to address key sustainability challenges in the construction sector. A circular economy approach prioritises waste minimisation, material reuse, and sustainable design, ensuring that building components are efficiently produced, utilised, and repurposed. However, IBS adoption faces several barriers, including low awareness, fragmented implementation strategies, and reliance on foreign technology. This paper examines these challenges and proposes solutions such as regulatory support, stakeholder collaboration, and technological advancements to enhance IBS sustainability. By embracing circular economy principles, the construction industry can transition from a linear "take-make-waste" model to a regenerative system, fostering economic growth, environmental conservation, and long-term resilience. This study highlights the crucial role of governmental policies, industry cooperation, and innovative technologies in facilitating this transformation.

KEYWORDS: Circular Economy, Industrialized Building System (IBS), Sustainable Construction, Waste Minimization, Prefabrication, Automation

Ref: 1st ICSIID//KHP/03

DEVELOPMENT OF COOLING BRICKS USING POWERPLANT BYPRODUCTS FOR IN-FIELD THERMAL COMFORT AND URBAN COOLING SIMULATION

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ABSTRACT: The increasing intensity of climate change demands sustainable strategies to alleviate urban heat and enhance thermal comfort, especially in hot regions. This study investigates the viability of coal bottom ash as a substitute construction material, emphasizing its use in brick production for thermal control. Although bottom ash is often seen as a waste byproduct of coal combustion, its significant porosity and water absorption characteristics provide potential for evaporative cooling in constructed settings. This study examines structural design development and thermal performance of bottom ash bricks using a mix of laboratory tests and numerical simulations using ENVI-met software. The research assesses their mechanical characteristics, moisture retention capability, and effectiveness in lowering surrounding air temperatures by direct evaporation. The experimental results demonstrate that a combination of 75% bottom ash and 25% cement attains optimum mechanical and thermal equilibrium. Moreover, ENVI-met simulations demonstrate that bottom ash bricks may significantly reduce urban heat by decreasing surface and air temperatures, rendering them a feasible option for sustainable building. This project advances circular economy ideas by reusing coal bottom ash into practical construction materials, so addressing environmental and urban climate issues. The results offer significant insights for incorporating waste-derived materials into climate-responsive design approaches, advancing the overarching goals of sustainable development and carbon neutrality.

KEYWORDS: Brick, Cement, Ash, Thermal comfort, Simulation

Ref: 1st ICSIID//KHP/04

A DUAL INDONESIA INSTITUTIONAL APPROACH TO MARITIME SUSTAINABILITY: ENVIRONMENTAL INITIATIVES BY PELINDO AND PERTAMINA

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ABSTRACT: Green Port and Smart Port, in 2023, an evaluation was conducted on seven companies operating under PELINDO, with performance ratings ranging from 58.97% to 72.76%. PELINDO has implemented various policies to reduce greenhouse gas emissions—one of the main causes of global warming and climate change—such as the electrification program for cargo handling equipment, which involves replacing diesel-powered generators with electric power sources. By the end of 2023, PELINDO had electrified 236 cargo handling units. In addition, PELINDO has optimized the use of recycled water, adopted B30 biodiesel fuel for cargo handling equipment as a more environmentally friendly renewable energy alternative, and ensured proper waste, wastewater, and garbage management in accordance with prevailing regulations to prevent negative environmental impacts. To reduce environmental risks and impacts, PELINDO allocated a total budget of IDR 85.49 billion (approx. USD 5.5 million) in 2023. PERTAMINA successfully reduced emissions by 6,866 tons of CO_2 equivalent, or 135% of its target of 5,090 tons CO_2 eq. This emission reduction was the result of several decarbonization initiatives, including speed regulation for vessels, conversion to LPG/LNG fuel, and an increase in the use of low sulfur fuel oil (LSFO)—a more environmentally friendly option. In 2022, LSFO accounted for 53.39% of total marine fuel use, marking an increase of 35.31% from the previous year. PERTAMINA also took climate adaptation measures by installing solar power plants (PLTS). In 2022, solar panels were installed at Tanjung Uban Terminal and Tanjung Sekong Terminal, contributing 2% of the total energy used. PERTAMINA has set a target to achieve 5% of energy use from solar power at these terminals by 2030.

KEYWORDS: Green Port, Smart Port, Maritime Sustainability, climate change, global warming

Ref: 1st ICSIID//KHP/05

SUSTAINABLE ENGINEERING: BUILDING A RESILIENT AND GREEN FUTURE

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ABSTRACT: Sustainability in engineering is no longer an option—it is a necessity. As the world grapples with climate change, resource depletion, and urban expansion, engineers and academics play a crucial role in shaping a sustainable future. This keynote will explore innovative approaches in structural engineering that enhance sustainability, including climate-resilient infrastructure, circular economy principles, and the integration of AI-driven solutions. Through real-world case studies and cutting-edge research, we will discuss how interdisciplinary collaboration, policy advocacy, and ethical responsibility can drive meaningful change. The session aims to inspire engineers and academics to embrace sustainability as a fundamental principle in education, research, and practice, ensuring a greener and more resilient built environment for future generations.

KEYWORDS: Sustainable Structural Engineering, Climate-Resilient Infrastructure, Circular Economy, AI-Driven Solutions, Green Building Technologies.

Ref: 1st ICSIID//KHP/06

THERMAL BLOCK: A SUSTAINABLE SOLUTION FOR WALL INSULATION

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ABSTRACT: The demand for sustainable and energy-efficient construction materials is increasing significantly due to rapid urbanization and global energy crisis. The present invention introduces a novel composite masonry block, namely "Thermal Block" designed to specifically address the growing energy demand in Pakistan, with a focus on reducing the cooling and heating loads in buildings. The Thermal Block consists of a normal concrete outer periphery with optimally designed geometry of cavities, filled with insulating material foamed concrete. This composition offers approximately 3-5°C higher temperature drop as compared to traditional concrete masonry blocks while maintaining adequate structural integrity. To develop this block, a structured four-phase research methodology was proposed, including material characterization, thermal simulations, experimental investigation, and real-time studio rooms construction for thermal performance monitoring. In this regard, thermal simulations using finite element analysis identified the most effective thermal block design that provided maximum temperature drop. It was then manufactured in the laboratory and experimentally evaluated for physical, mechanical and thermal properties. Results showed that the compressive strength of Thermal Block ranged between 600-1000psi, classifying it as suitable for non-load-bearing masonry. Additionally, it exhibited a 55% lower thermal conductivity (approximately 0.7 W/mK) than conventional concrete blocks, significantly improving thermal insulation. To further validate its compressive and shear strength, large-scale testing was conducted on thermal block prisms, wallets, and diagonal compression wall panels, yielding satisfactory results. Moreover, studio type rooms were constructed by using both Thermal Block and conventional concrete block to assess real-time thermal performance under varying seasonal conditions. Using data-logging thermocouples, infrared thermography, and sensors for CO_2 , humidity, and room temperature, a consistent 3–5°C reduction in indoor temperature was observed when using Thermal Blocks, endorsing its improved insulation capabilities. In brief, this research explores the development and effectiveness of Thermal Block in reducing building energy consumption and improving indoor thermal comfort, establishing it as a promising solution for sustainable construction in Pakistan.

KEYWORDS: Thermal Block, Energy-Efficient Construction, Thermal Insulation, Finite Element Analysis, Sustainable Masonry

Ref: 1st ICSIID//KHP/07

CHALLENGES, AND FUTURE PATHWAYS FOR GREEN MOBILITY IN KARACHI

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ABSTRACT: Karachi, the largest city in Pakistan's second most populous province of Sindh, is facing a twin crisis: rising air pollution and climate vulnerability. It is one of the most polluted urban centers in the world, with transportation responsible for 60% of PM2.5 emissions, which pose the greatest risk to health. Karachi's 4.2 million vehicles travel at an average speed of 18 km/h, leading to growing problems of emissions and fuel consumption. More than 90% of transportation depends on imported diesel and petrol, costing USD 2 billion annually (Sindh Transport Authority, 2023). Air pollution is responsible for 30% of respiratory diseases in Karachi, with children and the elderly being the worst affected (Jinnah Hospital, 2023). For sustainable transport in Amsterdam, the Netherlands representing a global success story by introducing the wind trams and electric car tax resulting reduction of transport emissions by 40% since 2010, Another successful project was implemented in Shenzhen, China, where 22,000 charging stations were built to provide charging services for 16,000 electric buses. Subsidies for e-rickshaws will increase adoption in Delhi, India, by 65% by 2022. Although the Sindh government has made commitments to sustainable transport, such as the Sindh Solar Power Project, which aims to achieve 400 MW of solar capacity by 2025 to power electric vehicle charging stations and public transport, and the Karachi Green Bus Project, which will use 50 electric buses, which will reduce carbon dioxide emissions by 60 tons per month on major routes (Sindh Public Transport). However, the challenges facing sustainable solutions include implementation barriers such as high upfront costs of electric vehicles and charging infrastructure, frequent power outages that affect the reliability of solar charging, preference for private cars and skepticism about the performance of electric vehicles, and lack of coordination between different agencies leading to excessive delays in project completion. In addition to above the policy reforms needs to be develop in line with Pakistan's current fiscal situation to reduce import duties on electric vehicles. Public engagement is essential to the success of any initiative through the social media campaign highlighting the economic and health benefits of a green Karachi. By analyzing current challenges, existing policies and global best practices, a multifaceted approach including electrification, renewable energy integration and social participation is proposed. Furthermore, to highlight the socio-economic and environmental benefits of green mobility is need of the hour by addressing barriers to its implementation and provide practical recommendations. So, detailed research is required for introducing green mobility in Karachi, which can lessen climate risks, enhance the quality of life in the city, and set a pattern for Pakistan by connecting sustainable energy resources, promoting public-private partnerships and adopting supportive policies.

KEYWORDS: Green Mobility, Electric Vehicles, Renewable Energy, Public-Private Partnerships.

Ref: 1st ICSIID//KHP/08

WATER-SMART INFRASTRUCTURE: INNOVATIONS IN WATER CONSERVATION, MANAGEMENT, AND RECYCLING IN CIVIL ENGINEERING

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ABSTRACT: Water scarcity is an escalating global challenge, necessitating innovative solutions in civil engineering and infrastructure development. This paper explores the concept of Water-Smart Infrastructure (WSI)—an integrated approach that optimizes water conservation, management, and recycling within urban and rural settings. By leveraging cutting-edge technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), and advanced water treatment systems, this study highlights transformative solutions for sustainable water use in smart cities, industrial applications, and residential systems. The paper presents case studies from successful water-smart projects worldwide, analyzing their impact on water efficiency, economic feasibility, and environmental sustainability. It also discusses the barriers to large-scale implementation, including financial constraints, policy gaps, and technological limitations, while proposing a roadmap for Pakistan and other water-stressed regions. By integrating data-driven water management, rainwater harvesting, and wastewater recycling, Water-Smart Infrastructure can redefine the future of urban planning and climate resilience. The findings emphasize the urgent need for collaborative efforts among policymakers, engineers, and researchers to establish sustainable water ecosystems. The paper concludes with actionable recommendations for transforming traditional infrastructure into adaptive, water-efficient systems that mitigate climate change impacts and ensure long-term water security.

KEYWORDS: Water-Smart Infrastructure, Sustainable Water Management, Smart Cities, Climate Resilience, IoT, AI in Water Conservation

Ref: 1st ICSIID//KHP/09

INNOVATIVE USE OF INDUSTRIAL STEEL SCALE WASTE IN HIGH-PERFORMANCE CONCRETE FOR SUSTAINABLE CONSTRUCTION

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ABSTRACT: Concrete, the foundation of modern infrastructure, is also one of the largest consumers of natural resources. Excessive extraction of natural resources such as sand and aggregates for concrete production leads to their depletion, accelerates environmental degradation, and may contribute to climate change. Meanwhile, several industrial by-products and wastes like steel scale waste often end up unused. This study explores an innovative and sustainable way to recycle steel scale waste as a partial replacement for fine aggregates in high-performance concrete. Through lab-scale testing of fresh and hardened concrete properties, the research determines optimal replacement levels of steel scale waste that maintain workability while enhancing compressive strength. The results suggest that steel scale waste, when cautiously employed, not only exhibits satisfactory performance but may also contribute to environmental conservation.

KEYWORDS: Steel Scale Waste, High-Performance Concrete, Fine Aggregate Replacement, Compressive Strength, Environmental Conservation.

Ref: 1st ICSIID//KHP/10

DOES SAFETY VOICE INFLUENCE WORKERS' SYSTEMATIC PROBLEM SOLVING: EXAMINING THE MEDIATING ROLE OF PERCEIVED SAFETY KNOWLEDGE ARTICULATION OF WORKERS

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ABSTRACT: Workplace safety remains a critical concern in high-risk industries like construction, where effective communication and problem-solving are essential for accident prevention. Workers' safety voice—the willingness to speak up about safety concerns—plays a vital role in fostering a proactive safety culture. However, limited research examines how safety voice translates into systematic problem-solving behaviors. This study explores perceived safety knowledge articulation as a key mediating mechanism in this relationship. Workers who effectively express safety knowledge may be better equipped to analyze safety issues systematically, identify root causes, and implement strategic solutions. Understanding this mediation process is crucial for enhancing workplace safety and operational efficiency. Using Partial Least Squares Structural Equation Modeling (PLS-SEM), data from 109 construction workers were analyzed to examine these relationships. The findings reveal that workers' safety voice significantly influences their systematic problem-solving approach, with perceived safety knowledge articulation serving as a critical mediator. These results highlight the importance of fostering an environment where workers feel encouraged to voice safety concerns and share knowledge. This study contributes to workplace safety literature by providing empirical evidence on how organizations can leverage safety voice to enhance problem-solving capabilities. The findings offer practical implications for safety management, emphasizing the need for policies that promote open communication and structured problem-solving approaches in the construction industry.

KEYWORDS: Safety, Systematic Problem Solving, Workers' Safety Voice, Construction Industry, PLS-SEM.

Ref: 1st ICSIID//KHP/11

URBAN ADAPTATION PLANNING: A TRANSFORMATIVE APPROACH TO BUILDING SUSTAINABLE AND RESILIENT CITIES FOR THE FUTURE

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ABSTRACT: Urban adaptation planning is increasingly recognized as a transformative approach to building sustainable and resilient cities capable of addressing challenges posed by climate change, rapid urbanization, and environmental degradation. Integrating urban planning with climate change adaptation is essential for effective urban resilience. This requires embedding adaptation principles into existing urban planning frameworks, including zoning regulations, land use plans, building codes, and disaster risk management strategies, as well as the psychosocial fabric of the cities. This study focuses on the urban adaptation planning framework perspective, emphasizing the integration of adaptation strategies into urban policies and design processes. It aims to reconceptualize adaptation not as an isolated process but as a mainstream approach across physical, social, economic, ecological, and institutional dimensions. In this context, data was collected from flood-prone communities in Islamabad, Pakistan, to assess their awareness of adaptation strategies at macro, meso, and micro scales. Macro adaptation strategies involve awareness of Nature-based Solutions (NbS), meso strategies focus on structural modifications, and micro adaptation strategies relates to behavioral changes in response to known hazards. The findings revealed the prevalent application of micro and meso adaptation strategies, while macro adaptation strategies were less commonly implemented. These results underscore the need to integrate adaptation strategies into urban planning frameworks, policies, and development plans to enhance community resilience and promote sustainable urban development.

KEYWORDS: Adaptation, Urban Planning, Resilience, Sustainability.

Ref: 1st ICSIID//KHP/12

3D CONCRETE PRINTING: CHALLENGES AND OPPORTUNITIES FOR CONSTRUCTION INDUSTRY IN PAKISTAN

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ABSTRACT: Additive manufacturing in the construction industry is predominantly implemented in the form of 3D concrete printing (3DCP). 3DCP involves the layer-by-layer deposition of a special printable concrete mix from an extruder capable of precise movement through a computer operated motion control system. The model to be printed is designed in computer-aided design (CAD) environment and is then fed to software which translates it into machine readable coordinates which are ultimately used to print the model in the real world. 3DCP is being actively researched to provide a cost-effective, less labor-intensive, time-efficient and sustainable solution to the global housing crisis and to provide rapid housing in disaster-struck areas. A complete 3DCP system includes a concrete printing setup and an associated printable concrete mix design, with the concrete mix optimization the key task. The current global challenges include minimal carbon footprint printable mix designs and lack of universally accepted 3DCP standards. In Pakistan, construction industry is traditionalist and is not receptive to change, as 3DCP is modern, so the industry is reluctant to accept it. Additionally, the required motion control system must be sourced internationally and there is a lack of automated construction experts which make the adoption more difficult. Despite these challenges, 3DCP has immense potential for Pakistani construction industry. As Pakistan is still developing and the need for affordable and quick to construct housing is more than ever and 3DCP has the capability to fulfil this demand especially as it is inherently scalable.

KEYWORDS: Additive manufacturing, automated construction, computer-aided design, 3D concrete printing, printable concrete mix

Ref: 1st ICSIID//KHP/13

AN INVESTIGATION ON USE OF LOCAL METAKAOLIN AS A CEMENT SUBSTITUTION MATERIAL: A SUSTAINABLE CONSTRUCTION MATERIAL

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ABSTRACT: Due to manufacturing of cement different harmful gases like CO_2, SO_3 and NOx are emitted into the atmosphere. The huge amount of energy is required to manufacturing cement and the cement price is rising day by day. The objective of this study is to explore and introduce indigenous natural material Soorh as pozzolanic material i.e., which is environmental friendly cement replacement material which is available in billions of tones in the locality of Thatta district Sindh. In this regard soorh is heated at various temperatures with different durations like 650°C, 700, 750°C & 800°C for 2-, 3- and 6-hours' time and at temperatures of 900°C and 1000 °C for 1- and 2-hours interval respectively. From the outcomes of chemical composition and strength activity index 800°C for 2 hours duration is the most suitable which fulfils the prerequisite of pozzolanic material as well as metakaolin as per ASTM C-618 that can be used as cement replacement material in concrete/mortar. The cement was replaced with local metakaolin which is produced at 800°C for 2 hours duration 5 to 25% by the weight of cement. The effect of local metakaolin on fresh and hardened properties of concrete were investigated. On the bases of the results of different investigated proprieties of concrete it is concluded that all the properties are improved at 15% replacement of cement by indigenous metakaolin as compared to control mix.

KEYWORDS: Chemical composition Metakaolin, Pozzolanic Material, Soorh, Strength Activity Index

Ref: 1st ICSIID//KHP/14

FINITE ELEMENT ANALYSIS OF STEEL PLATE GIRDERS: STRUCTURAL BEHAVIOR, FAILURE MECHANISMS, AND DESIGN OPTIMIZATION

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ABSTRACT: Steel plate girders are pivotal in modern infrastructure, yet their physical testing remains resource-intensive. This study leverages Finite Element Modeling and Analysis (FEM&A) to numerically investigate the structural behavior of steel plate girders, focusing on its failure mechanisms. Linear and nonlinear analyses were conducted on thin plates and girders under compressive loading, with validation performed against theoretical and pre-existing frameworks. Results demonstrated strong agreement between numerical predictions and theoretical benchmarks. Increased plate thickness significantly improved buckling resistance, highlighting the role of geometric parameters in structural performance. The study underscores FEM's capability to capture complex nonlinear behaviors, offering a cost-effective alternative to physical testing. By enabling efficient parametric studies and design optimizations, this approach equips engineers with critical insights for assessing and strengthening steel girders under diverse loading scenarios. The findings advance FEM applications in structural engineering, promoting safer and more sustainable infrastructure systems.

KEYWORDS: Finite Element Modeling, Steel Plate Girders, Elastic Buckling, Nonlinear Analysis, Parametric Study.

Ref: 1st ICSIID//KHP/15

REDEFINING INFRASTRUCTURE STANDARDS FOR SUSTAINABLE AND AFFORDABLE HOUSING: AN INTEGRATED APPROACH TO URBAN PLANNING FOR DEVELOPING CITIES

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ABSTRACT: Cities in developing countries are undergoing rapid and often unplanned urban expansion, with some of the highest urbanization rates globally. The increasing demand for essential urban functions, including housing, social amenities, and infrastructure, has outpaced the capacity of existing systems. Limited resources and unequal capital allocation have exacerbated housing disparities, resulting in a stark contrast between high-end luxury developments and substandard housing, leaving a significant portion of the population without access to adequate and affordable housing. In Pakistan, despite various initiatives by provincial and federal governments to promote affordable housing, many projects have failed to achieve their intended outcomes. The primary reasons include the absence of a systematic approach and inadequate control over key cost determinants such as land acquisition, construction expenses, and infrastructure development costs. Among these, infrastructure costs constitute a major portion of the overall project expenditure, largely due to rigid regulatory requirements that mandate a minimum set of infrastructure standards for housing schemes. These regulations, while intended to ensure quality and functionality, often impose financial burdens that make affordability unattainable for low- and middle-income populations. Addressing this challenge requires a critical re-evaluation of infrastructure requirements embedded in housing scheme regulations. There is an urgent need to develop new, context-specific standards that align infrastructure provisions with financial feasibility while ensuring long-term social, economic, and environmental sustainability. This research examines the impact of existing infrastructure standards on project costs and proposes a revised framework that integrates cost-efficiency with sustainable development principles. By redefining infrastructure requirements, this study aims to bridge the gap between affordability and quality, ensuring inclusive urban growth in rapidly expanding cities.

KEYWORDS: Urban expansion, affordable housing, infrastructure costs, regulatory requirements, and sustainable development.

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AI IN CIVIL ENGINEERING: DISRUPTING STAGNATION THROUGH INDIGENOUS INNOVATION

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ABSTRACT: Artificial Intelligence has been providing unprecedented opportunities to optimize processes and drive innovation. However, Civil and Structural Engineering has been lagging in the integration of technologies resulting in stagnant improvement over the last five decades, while every other industry has thrived. This keynote focuses on indigenous innovation led by Civil Engineers trained in AI to address local challenges in a resource-constrained environment. This talk introduces homegrown solutions designed by the “Applications of AI in Civil Engineering” Research group for Realtime construction progress monitoring, resource management, and structural health monitoring in an environment where legacy systems are non-existent. As a case study, a prototype, SHM system for damage detection is presented. Where a sensor network will be fixed on the prototype bridge as a testbed and optimized for the continuous acquisition of data to the computer. These data would be analyzed and characterized for damage detection parameters. The testbed on the prototype bridge with controlled data will allow us to propose testbeds to be deployed on newly constructed systems (bridges or buildings) for health monitoring of those structures throughout their service life, using modern technology for damage detection. This keynote will emphasize combining traditional engineering knowledge with modern AI techniques. These innovations will allow the Civil and Structural Engineering sector to benefit from the advances in Artificial Intelligence and Industry 4.0.

KEYWORDS: Artificial Intelligence in Civil Engineering, Structural Health Monitoring (SHM), Construction Progress Monitoring, Resource Management in Engineering, AI-Driven Damage Detection.

Ref: 1st ICSIID//KHP/85

THE ROLE OF ENGINEERING COMMUNITY-BASED ADAPTATION TO CLIMATE CHANGE: PROTECTING INFRASTRUCTURE OF URBAN SINDH IN FUTURE

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ABSTRACT: Climate change poses significant threats to urban infrastructure in Sindh, Pakistan. Rising temperatures, changing precipitation patterns, and increased frequency of extreme weather events are compromising the resilience of urban systems. Engineering community-based adaptation (CBA) has emerged as a vital approach to enhance the resilience of urban infrastructure. This research explores the role of engineering CBA in protecting urban infrastructure in Sindh, focusing on Karachi, Hyderabad, and Sukkur. A mixed-methods approach was employed, combining surveys, focus groups, and expert interviews. Data was collected from 200 engineers, 50 community leaders, and 20 experts in climate change and urban planning. The study reveals that engineering CBA can significantly enhance the resilience of urban infrastructure. Community-led initiatives, such as flood protection measures, climate-resilient construction practices, and early warning systems, have reduced the impact of climate-related disasters. The research also highlights the importance of community engagement, social cohesion, and institutional support in facilitating engineering CBA.

KEYWORDS: Climate change, Community-based adaptation, Engineering, Urban infrastructure, Resilience, Sindh, Pakistan, Sustainable development, Disaster risk reduction.

Abstract Submissions

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INTEGRATING MODULAR CONSTRUCTION AND AMPHIBIOUS HOUSING FOR CLIMATE RESILIENT SOLUTIONS IN FLOOD-PRONE AREAS OF PAKISTAN

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ABSTRACT: Annual floods in Pakistan are a very severe challenge, as millions of people are displaced and local infrastructure is devastated. Amphibious housing technology paired with modular construction practices provides climate-resilient housing solutions for the flood crisis. This paper proposes integrating modular construction principles with amphibious housing technology to provide sustainable and scalable solutions for flood-prone regions, especially in lower Punjab and Sindh. It employs light gauge steel as the predominant material for the superstructure. It also allows for adaptability to the increased water levels on the basis of buoyancy. The prefabrication off the site reduces the construction time and the costs while still maintaining the level of quality. Housing modules can easily be transported into remote regions in order to fasten deployment. From a design point of view, modularity provides the opportunity for customization to accommodate diverse community needs, from single-family units to larger housing clusters. The structural analysis and subsequent design of the amphibious house will be conducted by considering the predominant force parameters applied by the low-velocity flood as is observed in Lower Punjab and Sindh. This integration fits with the objectives of sustainable infrastructure. Objectives such as reducing the waste of material, optimizing available resources, and minimizing environmental damage. The paper also studies some potential market barriers and rate of adoption of modular-amphibious housing in Pakistan. This research would join modular construction aims to create a benchmark for sustainable, resilient infrastructure in climate-vulnerable regions.

KEYWORDS: Amphibious Housing, Modular Construction, Climate Resilience, Superstructure, Light Gauge Steel, Buoyancy, Climate-Vulnerable Regions.

Ref: 1st ICSIID//KHP/19

THE ROLE OF MUSLIM ARCHITECTURE IN URBAN PLANNING TO PROMOTING RELIGIOUS TOURISM IN URBAN AREAS OF PAKISTAN: A CASE STUDY OF MULTAN

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ABSTRACT: Tourism is a significant driver of economic growth. Religious tourism is deeply rooted in spiritual, cultural, and historical contexts. It can foster spiritual and human growth and is critical to socioeconomic development. Multan is a developed city with historical sites and cultural significance. It attracts more tourists through the spatial practices of the shrines in the city centers. This research helps examine the characteristics of different Sufi shrines. The major categories include Architectural elements, Land Use, Utilities, Environment, Transportation and Accessibility in and around the shrines. The study contains a sample size of 13 different shrines in the city area. The observational survey has been done. The data was collected through a complete set of indicators which was composed from the relevant literature. The data was analyzed using descriptive analysis to understand the differences in the shrines. The analysis revealed that the majority of the shrines were generally less in infrastructural development and recreational activities. However, the classification indicates that the large shrines have more facilities whereas small shrines are neglected which affects both the tourists and the worshippers. The findings reveal that there is a need for urban planners to work in this regard.

KEYWORDS: Architecture, Culture, Economic, Infrastructure, Pilgrimage.

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INVESTIGATING THE STRUCTURAL BEHAVIOR OF FLEXIBLE PAVEMENT WITH RECYCLED AGGREGATES AND PLASTIC MODIFICATIONS

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ABSTRACT: The waste plastic is generally dumped into the oceans, and the waste generated from construction and demolition activities is generally dumped into the landfill activities. This dumping activity is contributing to the environmental degradation. This material can be reused in construction activities. In this study, the behaviour of asphalt pavement with the modification of plastic in different percentages, like 0%, 20%, and 40% of natural aggregates replaced with recycled coarse aggregates (RCA), was investigated. Besides, a series of experiments using different levels of RCA was conducted to determine the physical properties such as air voids and density. The results of the experiments conducted on the Marshal mix sample showed that the air voids reduce with the increase in the asphalt content, while when RCA is added, then air voids are increased more than natural. Moreover, the density is increasing with an increase in the percentage of asphalt content up to a certain level, and then it starts decreasing; when the addition of RCA is increased, its density decreases. It has been found that the use of construction and demolition waste in the construction industry is not only to reduce the waste but also to recycle it, and then it will be utilized for commercial purposes.

KEYWORDS: High Seismic Performance, Shear Wall density, Bracing and Steel Frame

Ref: 1st ICSIID//KHP/22

EFFECT OF CONOCARPUS TREE WASTE LEAVES FLY ASH AS CEMENTITIOUS MATERIAL ON FRESH AND HARDENED PROPERTIES OF CONCRETE

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ABSTRACT: The production of cement generates about 7% of the world's CO_2 emissions, which significantly impacts the environment, and making the construction industry a significant contributor to global warming. Therefore, this study purpose is to use conocarpus tree waste leaves fly ash as replacement for cement in concrete, to decrease consumption of cement and mitigate its negative impacts. In this research work, total 24 concrete samples (12 cubes, and 12 cylinders) inclusion with 0%, 5%, 10%, and 15% of conocarpus trees leaves fly ash as replacement for cement were prepared by using 1:1.5:3 mix proportions at 0.50 water-binder ratio. Besides, these samples were tested for workability, and compressive strength at 7 days respectively. The findings declared that the workability of concrete is decreasing as the conocarpus trees leaves fly ash content increases in concrete. Moreover, a decrease in compressive strength is recorded with an increasing percentage of conocarpus tree fly ash compared to conventional concrete. From experimental outcomes, it has been found that higher incorporation of Conocarpus tree fly ash negatively affects these properties; therefore, it is recommended to explore alternative additives to mitigate these negative effects while maintaining sustainability.

KEYWORDS: Conocarpus Trees Leaves Fly Ash; Concrete; Workability; Hardened Properties; Reduce CO2 Emission.

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INVESTIGATING THE FACTORS ENHANCING THE INDUSTRIALIZED BUILDING SYSTEM(IBS) IN CONSTRUCTION INDUSTRY

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ABSTRACT: The construction industry is moving towards modern construction methods, which aim to provide faster construction, higher quality, efficiency, environmental friendliness, safety, reduced waste and pollution, and improved supervision and management. The Industrialized Building System (IBS), sometimes called Modular Construction, effectively addresses these needs. Therefore, this research investigates the status of the IBS and the factors that promote its development within the construction industry. To conduct this research, respondents were given survey questionnaires to identify development-enhancing factors of IBS. Besides, the data analysis was performed by using SPSS 16.0 and Excel 2019. The results indicate a need to promote IBS in the construction industry. Moreover, the primary advantages of IBS identified were a reduction in construction completion time and a decrease in waste. It was observed that the key factors enhancing IBS development include better incentives for skilled workers and the need for more durable (efficient) design and construction.

KEYWORDS: Construction, sustainability, Industrialization, Efficiency, Prefabrication

Ref: 1st ICSIID//KHP/24

THE DEVELOPMENT OF GEOPOLYMER CONCRETE BY USING LOCALLY AVAILABLE FLY ASH

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ABSTRACT: The construction industry significantly contributes to global warming through the production of Portland cement, a major binder in concrete. As a result, there's a growing interest in alternative substances like fly ash to reduce the need for Portland cement. This study was conducted to develop Geopolymer Concrete (GPC), a zero-cement alternative that uses fly ash as a binder instead of Portland cement. A total of 15 cubical GPC samples were prepared with 1:2:4 mix proportions and tested for compressive strength at 7 and 28 days, respectively. The results indicated good compressive strength with the addition of fly ash as a binder. Notably, the workability and compressive strength of GPC were significantly influenced by the sodium silicate to sodium hydroxide ratio, alkaline solids to fly ash ratio, aggregate content, and water to solids ratio. Increasing the sodium silicate to NaOH ratio from 1.3 to 2.5 improved workability and led to similar compressive strengths of 57.6–58.5 MPa, but higher ratios resulted in reduced strength. Moreover, the compressive strength increased with the alkaline solids to FA ratio, peaking at 58.5 MPa for a ratio of 0.37, but decreasing with further increase in the ratio. The study observed that fly ash-based GPC offers good outcomes, reduces the carbon footprint, and contributes to a sustainable environment. Therefore, it is recommended for use in the construction industry as a sustainable alternative to traditional concrete.

KEYWORDS: Geopolymer Concrete, Fly Ash, Compressive Strength, reduce carbon dioxide, Sustainable Environment.

Ref: 1st ICSIID//KHP/32

EFFECT OF NOZZLE STANDOFF DISTANCE ON PRINT QUALITY AND FLEXURAL BEHAVIOUR OF PLAIN AND PP FIBER REINFORCED 3D PRINTED CONCRETE BEAMS

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ABSTRACT: While extensive research focuses on optimizing concrete mixtures for 3D printing, selecting appropriate printing parameters is equally critical for the performance of 3D printed structures. This study investigates the effect of nozzle standoff distance on the print quality and flexural strength of 3D printed concrete beams, examining both plain beams and those reinforced with 12.5 mm polypropylene (PP) fibers. Beams are printed using three nozzle standoff distances, 10 mm, 12.5 mm, and 15 mm, to evaluate how this parameter influences layer quality, interlayer adhesion, and, in reinforced beams, fiber orientation, and integration. Print quality is assessed through visual inspections, while flexural strength is determined using the three-point bending test. The results indicate that nozzle standoff distance significantly affects the mechanical performance of both plain and fiber-reinforced beams. An optimal standoff distance is identified that enhances surface finish and mechanical performance. These findings provide valuable insights for optimizing printing parameters in extrusion-based 3D concrete printing, contributing to the development of more robust and efficient construction methods.

KEYWORDS: 3D concrete printing, fiber reinforcement, mechanical properties, nozzle standoff distance, print quality

Ref: 1st ICSIID//KHP/33

LIGHTWEIGHT CONCRETE INCORPORATING PUMICE STONE AS A FINE AGGREGATE AND POLYPROPYLENE FIBER FOR ENHANCED PERFORMANCE

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ABSTRACT: This paper provides an investigation on the formation of lightweight concrete incorporating pumice stone as a fine aggregate in presence of polypropylene (PP) fiber. However, the pumice Stone is as a lightweight aggregate has many benefits including low density and excellent thermal insulation properties. Considering the merits of pumice stone, this study investigated the effects of fine aggregate replacement with pumice stone at different proportions 0%, 10%, 20%, 30% by weight of fine aggregate. Firstly, the workability of fresh concrete was evaluated then the density and compressive strength of hardened concrete were checked. It was observed from the experimental findings the workability of concrete was enhanced due to incorporation of pumice stone and PP fiber. The density and compressive strength were found to be reduced as compared to the control mix concrete. Based on the compressive strength tests results the optimal performance was noticed at 20% pumice replacement with PP fiber. Whereas, the addition of PP fibers positively affects the mechanical properties of concrete.

KEYWORDS: Pumice Aggregate, Polypropylene Fiber, Workability, Density and Compressive Strength

Ref: 1st ICSIID//KHP/34

FLOOD RISK COMMUNICATION INFRASTRUCTURE FOR RISK REDUCTION AND RESILIENCE

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ABSTRACT: Effective risk communication is essential for reducing flood risk and enhancing community resilience. Many studies have been done on structural measures, but very few have focused on non-structural measures for flood risk reduction and community resilience. This study aims to explore and evaluate the existing flood risk communication infrastructure in the River Swat Region of District Swat. By assessing the existing communication strategies and their effectiveness, this study highlights the strength of the current communication infrastructure and identifies areas for improvement of flood risk reduction. It focuses on the clarity, timeliness, and accessibility of flood risk information dissemination, ensuring that the community is well-informed and prepared for flood events. The findings of this study also highlight the critical role of community engagement and the integration of advanced communication strategies that contribute to better preparedness and resilience. This research provides valuable insights into existing communication strategies and infrastructure and recommendations for future improvements for policy makers, practitioners, and stakeholders involved in flood risk management.

KEYWORDS: Communication Strategies, Community Resilience, Flood Risk Communication, Non-Structural Measures, Preparedness and Engagement

Ref: 1st ICSIID//KHP/39

ASSESSMENT OF DRINKING WATER QUALITY OF PRIMARY SCHOOLS AND MOSQUES OF NAWABSHAH CITY

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ABSTRACT: A research investigation was conducted to evaluate and examine the drinking water quality of primary schools and Mosques of the Nawabshah city. Six locations of primary schools and four locations of Mosques within the city were selected for the testing purpose. Samples were collected in the month of September. Twelve physicochemical parameters (Taste, Odor, Color, pH, Turbidity, Chlorides, Hardness, Total dissolved Solids, Sulfates, Nitrates, Dissolved Oxygen) and one biological parameter were tested. Each sample's parameters were compared with (World health organization) WHO guidelines. The Results of all the samples demonstrated that all samples passed the limits of the PH, Nitrate, Hardness and Dissolved Oxygen. 30% samples crossed the WHO limits for Turbidity. 40% samples crossed the WHO limits for TDS. 100% samples crossed the WHO limits for E-Coli. 20% samples crossed the WHO limits for Chlorine. 30 % samples crossed the WHO limits for sulphates. Overall, the Drinking water quality of the primary schools and Mosques of Nawabshah city is Un-fit. Most of the schools and Mosque's failed the WHO standards for most of the parameters.

KEYWORDS: Nawabshah, Primary schools, MOSQUE'S Physicochemical, Drinking water, Results, World Health Organization (WHO), Guidelines, Total Dissolved Solids (TDS), E-Coli, Sulfate, Water quality, Improvement, Blending, Treatment systems, Standards

Ref: 1st ICSIID//KHP/40

UTILIZATION OF RECYCLED WASTE GLASS AS A FULL REPLACEMENT FOR FINE AGGREGATE IN CONCRETE: STRENGTH AND FEASIBILITY ANALYSIS

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ABSTRACT: The increasing accumulation of waste glass embodies an environmental hazard due to its non-degradable character and an equally inefficient recycling process. This study examined the feasibility and mechanical performance of a concrete mix with 80 kg of crushed recycled waste glass as a complete replacement for fine aggregate. The concrete specimens were cast and tested for compressive strength at 3, 7, and 28 days to assess their strength development. Results show that the average strength development for the composite concrete was 11.97 MPa at 3 days, 17.38 MPa at 7 days, and 20.815 MPa at 28 days—this translates to increased strength by 25.6% over the control concrete, which attained 16.57 MPa at 28 days. The maximum strength characteristics were observed at 100% fine aggregate replacement with crushed waste glass because of improved particle packing and densification of the concrete matrix. Further particle size distribution and mix proportion optimization will produce even better performance. This shows a large promise for the possibilities of recycled waste glass as an eco-friendly and sustainable alternative to natural fine aggregate.

KEYWORDS: compressive strength, concrete, recycled waste glass, sustainability, waste management.

Ref: 1st ICSIID//KHP/41

STRENGTHENING MECHANISM OF BAMBOO FIBER CONCRETE UNDER SPLITTING TENSILE LOAD

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ABSTRACT: Bamboo fiber concrete is gaining attention for its sustainability and mechanical benefits, yet its strengthening mechanisms remain underexplored, despite its promising potential, there is limited research on how bamboo fibers interact within the concrete matrix to enhance tensile performance. Understanding these mechanisms is crucial for optimizing fiber content and improving overall structural integrity. This study examines its splitting tensile behavior through experimental testing, theoretical modeling, and comparative analysis. Splitting tensile tests were conducted using a universal testing machine with varying fiber content and fiber length (10 mm, 20 mm, and 30 mm) with a rectangular cross-section of 15 mm × 20 mm. Tensile tests on bamboo fibers were also performed to assess intrinsic strength. Theoretical predictions based on composite material theory and fiber spacing theory was validated against experimental results. Findings show that composite material theory yields significant errors (30–45%) due to unrealistic assumptions, while fiber spacing theory provides accurate predictions (error <5%) for fiber contents up to 0.26 kg/m^3. Increasing fiber content enhances tensile strength up to an optimal level, but excessive fibers reduce strength due to non-uniform distribution. These results confirm the suitability of fiber spacing theory in modeling bamboo fiber reinforcement, supporting its use in sustainable concrete applications.

KEYWORDS: Eco-friendly concrete reinforcement, Fiber-reinforced sustainable materials, and Innovative structural composites

Ref: 1st ICSIID//KHP/43

SMART TRAFFIC MANAGEMENT USING MACHINE LEARNING AND IMAGE PROCESSING FOR URBAN CONGESTION REDUCTION

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ABSTRACT: Urban traffic congestion is a significant challenge in modern cities, leading to delays, increased fuel consumption, and inefficiencies in transportation networks. Traditional traffic management systems often lack real-time analysis and predictive capabilities. This study aims to address these limitations by utilizing modern technologies such as computer-based modeling, machine learning, and image processing to analyze and mitigate traffic congestion. The project leverages Good Vision Software, a smart tool for processing visual data, to detect and track vehicles, identify congestion points, and analyze traffic patterns. Real-time traffic footage will be collected from selected urban locations and processed using advanced image recognition and data analytics techniques. Machine learning models will be developed to predict peak traffic hours and congestion trends, enabling proactive traffic management strategies. By integrating real-time analysis with predictive modeling, the study will provide data-driven recommendations to enhance urban mobility. The expected outcomes include a real-time congestion detection system, identification of high-traffic zones, and optimized traffic flow strategies. The findings will contribute to efficient urban traffic management, reducing delays and improving overall transportation efficiency.

KEYWORDS: Urban Traffic Congestion, Machine Learning, Image Processing, Real-Time Traffic Analysis, Predictive Modeling, Smart Transportation, Traffic Flow Optimization, Good Vision Software, Congestion Detection, Data-Driven Traffic Management.

Ref: 1st ICSIID//KHP/45

PERFORMANCE EVALUATION OF ACETONE-TREATED EXPANDED POLYSTYRENE ANGULAR LIGHT WEIGHT AGGREGATES FOR RIGID PAVEMENTS

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ABSTRACT: Expanded polystyrene (EPS) waste has raised environmental concerns due to its abundant use in disposable items. Although EPS provides advantages in construction by decreasing structural loads, its integration into concrete compromises mechanical performance, restricting wider application. This work mitigates this constraint by investigating an innovative method: producing angular lightweight coarse aggregates (ALCA) from EPS waste utilizing acetone as a solvent, with the intent of using it in structural concrete for rigid pavements and evaluating their performance as aggregates and in the concrete mix versus normal aggregates while adhering to circular economy principles and conserving natural aggregate sources. The methodology involved fabricating ALCA by dissolving EPS waste in acetone and letting it dry, followed by breaking it into ALCA. By dissolving EPS in acetone, its volume reduces, significantly increasing EPS diversion per concrete batch, and drying it results in an ALCA, which is apparently harder than the usual EPS beads used in concrete. The replacement ALCA composition used in concrete is 0%, 15%, 50%, and 100%. The results indicated that ALCA are 3.8 times lighter and have 14.3 times more absorption capacity, while being 3.9 times more impact resistant and 1.7 times more abrasion resistant relative to normal aggregates but lack crushing resistance. Additionally, increasing LWA content from 15% to 100% leads to compressive strength reduction from 14.77% to 63.46% and dry density reduction from 4.01% to 24.52% compared to conventional concrete. Thus, ALCA can be used for rigid pavements, but for high load demands, lower ALCA proportions should be used.

KEYWORDS: Angular Lightweight Coarse Aggregates (ALCA), Circular Economy, Expanded Polystyrene (EPS), Performance Evaluation, Rigid Pavements

Ref: 1st ICSIID//KHP/46

ASSESSING REGIONAL CLIMATE MODELS WITH S-NSM AND SUBR: A CASE STUDY OF REMO, RCA4, AND REGCM4.2 FOR KARACHI CITY

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ABSTRACT: Regional Climate Models (RCMs) capture localized variations but their performance remains debated. The proposed framework validates RegCM4.2, REMO, and RCA4 using ERA5 daily land data for Karachi's maximum and minimum temperatures from 1981 to 2005, with a strict prediction of 90% and above. S-NSM, capable of capturing minor variations, measures the relative similarity between predicted and actual temperatures, linking comparative performance via similarity matrices.

Performance is classified into six classes: A (98–100), B (96–98), C (94–96), D (92–94), E (90–92), and F (<90), each associated with SUBR utility values of 1, 0.8, 0.6, 0.4, 0.2, and 0, respectively. First, similarity matrices are organized into performance matrices based on these classes. Next, counts in each class are multiplied by the corresponding SUBR utility value to create SUBR performance class matrices, which are then summed to yield the aggregated SUBR performance matrices.

REMO performs best for both extremes. For max temperature, REMO (3696) leads RCA4 (3485) and RegCM4.2 (1704), dominating all years except 1989, 1993, and 1998, when RCA4 ranks first. For min temperature, REMO (2729) leads with RegCM4.2 (2326) surpassing RCA4 (2139), dominating 20 years, while RegCM4.2 leads in 1988, 1992, 1993, 1997, 1998, and 2004. Average annual performance is REMO (147.83, 109.18), RCA4 (139.39, 85.52), and RegCM4.2 (68.17, 93.04) for max and min temperatures, respectively. REMO dominates all seasons, especially JJAS for min temperature. RCA4 is competitive in max temp (ONDJ) but fails in min temp (FMAM), while RegCM4.2 underperforms in max temp during ONDJ.

KEYWORDS: Performance Evaluation, Regional Climate Models, Shabir's Novel Similarity Measure (S-NSM), Shabir's Utility Based Reward (SUBR) Method, Temperature Extremes Assessment

Ref: 1st ICSIID//KHP/48

CHALLENGES AND MITIGATING MEASURES FOR THE IMPLEMENTATION OF BIM IN THE CONSTRUCTION INDUSTRY OF PAKISTAN

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ABSTRACT: Building Information Modelling (BIM) has evolved significantly since its inception in the 20th century, advancing alongside technologies such as CAD and now integrating AI and IoT, which have enhanced its global applications. The BIM is widely acknowledged for its role in streamlining construction processes, improving project efficiency, and fostering better collaboration among stakeholders. However, despite these advancements, the construction industry in Pakistan has been slow to embrace BIM and facing multiple challenges that hinder its adoption in the industry. This research aims to identify the key barriers preventing the implementation of BIM in Pakistan's construction industry. The study had two primary objectives: first, to identify the common challenges restricting BIM adoption in Pakistan, and second, to propose practical mitigating measures to overcome these challenges. To achieve this, semi-structured interviews were conducted with industry experts to gather their insights and recommendations. This research used qualitative approach to draws insights from experienced BIM professionals actively engaged in building projects within the country. A literature review was conducted to explore common challenges associated with BIM adoption, with a particular focus on Pakistan's construction landscape. Through a frequency-based analysis, eight critical challenges were identified from previous studies including, Lack of Skilled workforce, Lack of govt policies and Support, Resistance to Change as top three challenges. The findings offer valuable guidance from construction professionals, aiming to harness BIM effectively to minimize project delays, cut costs, and enhance overall project success in Pakistan's construction sector.

KEYWORDS: Building Information Modelling, Artificial Intelligence, Internet of Things.

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INTRODUCING TEKLA TEDDS FOR STRUCTURAL DESIGN: A PARADIGM SHIFT IN BUILDING ANALYSIS FOR PAKISTAN

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ABSTRACT: Designing commercial structures entails thorough examination to ensure safety, efficiency, and compliance with engineering codes. Engineers must consider various factors, including load distribution, material behavior, and regulatory requirements, to create strong and durable frameworks. Traditional structural analysis methods often involve lengthy calculations that are time-consuming and prone to errors. This study explores the use of Tekla Tedds, an advanced structural analysis and design software, in simplifying commercial building framework development. Tekla Tedds automates complex calculations related to load analysis, structural components, and material specifications, minimizing errors and significantly enhancing productivity. The research follows a structured standard according to Pakistan, step-by-step approach, covering everything from modeling and load application to design verification, ensuring strict adherence to relevant building codes and standards. This study shows that the software streamlines documentation and reporting, providing clear and precise design calculations that facilitate regulatory approvals. In conclusion Tekla Tedds proves to be an efficient tool for engineers seeking rapid and standardized calculations, making it ideal for routine structural design tasks, whereas other software may be better suited for complex structural modeling and in-depth analysis.

KEYWORDS: Building Code Compliance, Error Reduction in Structural Calculations, Load Analysis, Structural Design Automation, Tekla Tedds

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AUTOMATING REINFORCEMENT DETAILING IN REVIT: A CASE STUDY ON DYNAMO IMPLEMENTATION

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ABSTRACT: Structural engineering involves several aspects, one of which is reinforcement detailing, ensuring safety and performance standards in a structure. Traditionally, the placement of rebar in Autodesk Revit has been a manual process—one that is time-consuming, error-prone, and inefficient. In this context, this research explores the automation of reinforcement detailing using Dynamo scripting to enhance design accuracy and streamline workflow efficiency. A case study was conducted on a mid-rise commercial building, comparing manual and automated reinforcement detailing. Key performance metrics, including time efficiency, error frequency, adaptability to design changes, and cost savings, were analyzed. The results demonstrated a 60% reduction in modeling time using Dynamo, a decrease in errors from 15% to below 5%, and improved adaptability through instant design updates. Additionally, project costs were reduced by 30% due to fewer rework requirements. The findings suggest that the AEC industry would greatly benefit from the broader implementation of automation. The use of Dynamo scripting for reinforcement detailing has proven to be highly advantageous in terms of efficiency, accuracy, and cost reduction. Automation not only minimizes manual effort but also enhances adaptability to design changes, leading to more streamlined project execution. Dynamo scripting serves as a valuable tool for structural engineers and BIM professionals by reducing errors and optimizing resource allocation.

KEYWORDS: AEC (Architecture, Engineering, and Construction), BIM (Building Information Modeling), Dynamo Automation, Rebar Placement Optimization, Reinforcement Detailing, Structural Engineering

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PERFORMANCE EVALUATION OF JHAMA BRICK AS A PARTIAL COARSE AGGREGATE REPLACEMENT

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ABSTRACT: The replacement of natural coarse aggregates with Jhama brick (overburnt brick) in concrete has been widely explored to mitigate the cost and environmental issues. Various experiments by many researchers in the laboratory environment have demonstrated the replacement of natural coarse aggregates by using Jhama brick aggregates in the range of 10% to 50% influence on some concrete parameters. At lower replacement levels (10–25%), the compressive strength initially improved, peaking at 20–25% for the M25 grade. Various experiments by many researchers in the laboratory environment have demonstrated the replacement of natural coarse aggregates by using Jhama brick aggregates in the range of 10% to 50% influence on some concrete parameters. 12% compared to that of conventional concrete. However, at higher replacement levels (30–40%), the strength decreased by 3–28%, primarily because of the porous structure and high water absorption (6–20%) of the Jhama bricks. Workability, assessed by the compaction factor or slump test, decreases gradually with increasing replacement levels because the aggregates possess irregular shapes and surfaces. Structural lightweight concrete with unit weight ranging from 1,800–2,200 kg/m³ is attained by the replacement of aggregates by 25–30% using Jhama bricks, conforming to the specifications given by ASTM C330 while keeping the costs reduced by up to 14% by reducing transportation costs and handling waste. This approach promotes sustainable construction by repurposing industrial byproducts, reducing natural resource depletion, and lowering carbon footprints. Further research is required for long-term durability and large-scale applications.

KEYWORDS: Jhama brick aggregates, sustainable construction, lightweight concrete, industrial byproducts, carbon footprints.

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SOLAR PV MODULE RECYCLING: CHALLENGES, POLICIES, AND SUSTAINABLE SOLUTIONS

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ABSTRACT: With the adoption of solar energy climbing rapidly across the globe, handling end-of-life (EOL) photovoltaic (PV) modules has become even more challenging. Millions of PV panels are reaching an end-of-life. Developing sustainable and cost-effective recycling processes has become a matter of urgent importance for the renewable energy sector. Various recycling technologies are now emerging, but continued inconsistencies in global regulations, high processing costs, and weak policy enforcement impede large-scale adoption. This paper will identify and develop sustainable disposal techniques, recycling innovations, and policy frameworks towards successively closing these critical gaps. The study focuses on a systematic review on mechanical, thermal, and chemical recycling of photovoltaics and the assessment of extended producer responsibility (EPR). A comparative analysis of global policies such as WEEE Directive and programs in Sweden, Japan, India, Australia, and the EU are helpful in giving indications regarding various waste management strategies. Solutions to overcome existing barriers include the development of cost-efficient recycling technologies, the establishment of financial incentives to process PV waste, and the introduction of stricter global recycling regulations. The research points further to the need for industry participation and cooperation between policymakers, manufacturers, and researchers in building a circular economy around the sector to ease the recovery of valuable materials. In addition to this, the potential for investment into artificial intelligence and automation for sorting and processing PV waste could greatly enhance efficiency, whereas research into bioleaching and solvent-based recycling methods could offer greener alternatives. Setting up dedicated PV recycling units and considering second-life applications of degraded modules can help minimize waste and augment sustainability. Such long-lasting sustainability approaches promise the introduction of eco-friendly PV materials and design innovations for easy disassembly. They would also cause the solar industry to achieve a far more robust and environmentally responsible management system for the end-of-life fate of PV modules.

KEYWORDS: Solar photovoltaic (PV), PV Module Recycling, Sustainable Waste Management,

Renewable Energy Sustainability, Environmental Policy

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STRENGTH AND DURABILITY OF CONCRETE WITH BURNT SAWDUST ASH AS A CEMENT REPLACEMENT

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ABSTRACT: This research considered the use of saw dust ash as a pozzolan in the production of concrete. the study investigated the physical properties and chemical composition of saw dust ash (SDA) as well as the workability, and compressive strength properties of the concrete produced by replacing 0% and 5% by weight of ordinary Portland cement with SDA. Fineness decreases with increase of SDA. Soundness of cement increase with the increase of SDA %. More water is required as we increase the % of SDA. Slump tests were carried out on the fresh concrete and compressive strength test on hardened concrete. The concrete cubes were tested at the ages of 3 and 28 days. The results showed that SDA is a good pozzolan with combined SiO_2, Al_2O_3 and Fe_2O_3 of 73.07%. The slump decreased as the SDA content increased indicating that concrete becomes less workable as the SDA content increased. The compressive strength decreased with increasing SDA replacement. The compressive strength of concrete with SDA was lower at early stages but improves significantly up to 90 days.

KEYWORDS: Sawdust ash (SDA), sustainable construction, pozzolanic activity, strength development, cement replacement.

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MECHANICAL PROPERTIES OF ECO-FRIENDLY BRICKS UTILIZING DEMOLITION WASTE AND FLY ASH

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ABSTRACT: This study explores the feasibility of utilizing construction and demolition (C&D) waste, fly ash, and cement in brick production as an environmentally friendly replacement for traditional clay bricks. With increasing urbanization, the generation of C&D waste has led to significant environmental concerns, making its efficient reuse essential for sustainable infrastructure development. By integrating recycled materials into mainstream construction, these bricks provide a practical waste management solution while promoting environmentally responsible building practices. Their potential to enhance sustainability in the construction industry positions them as a promising innovation for the future of infrastructure development. This research highlights the environmental advantages of reducing landfill dependence, conserving natural resources, and lowering carbon emissions. Experimental analysis confirms that these bricks possess a compressive strength of 20.84 MPa, a water absorption rate of 18.77%, and a bulk density of 1473.77 kg/m³, ensuring durability, efficiency, and improved thermal insulation. These characteristics make them suitable for widespread construction use, offering cost savings and resource conservation. Additionally, the study emphasizes the economic viability of these bricks, as they reduce material costs while maintaining structural integrity.

KEYWORDS: Sustainable Construction, C&D Waste Utilization, Eco-friendly Bricks, Recycled Materials, Waste Management

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INFLUENCE OF SUGARCANE BAGASSE ASH AS A PARTIAL CEMENT REPLACEMENT IN PRESENCE POLYPROPYLENE FIBER ON THE COMPRESSIVE STRENGTH AND ELECTRICAL CONDUCTIVITY OF CEMENT MORTAR

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ABSTRACT: This study investigated the influence of polypropylene (PP) fiber in presence of sugarcane bagasse ash (SCBA) in mortar. This study focused on enhancing the sustainability through incorporation of SCBA as a partial cement replacement cement and addition of PP fiber. However, SCBA is an agricultural byproduct that was replaced 10%, 20%, and 30% of cement by weight. While PP fibers were added at fixed percentage as 1% by weight of cement. The primary objective was to evaluate the effects of SCBA in the presence of PP fibers on the compressive strength and electrical conductivity of the cement mortar. The electrical conductivity was measured using the probe method, and compressive strength test was evaluated throught compressive testing machine. The experimental findings reveal that the inclusion of PP fibers significantly reduces the electrical conductivity of the mortar, making it suitable for applications requiring insulating properties. Simultaneously, SCBA contributes to sustainable cement production by reducing the reliance on traditional cement, without compromising the mechanical integrity of the mortar. The study identifies an optimal mixture of 10% SCBA with 1% PP fibers, which achieves a harmonious balance between electrical conductivity and maintained compressive strength, and environmental sustainability.

KEYWORDS: Sugarcane Bagasse Ash, Polypropylene Fiber, Compressive Strength, Electrical Conductivity.

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EFFECT OF SUGARCANE BAGASSE ASH ON DURABILITY OF CONCRETE AT HIGH TEMPERATURES

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ABSTRACT: This study aims to evaluate the performance of concrete containing sugarcane bagasse ash (SCBA) as a partial replacement for cement exposed to elevated temperatures. Initially, SCBA was analyzed for its physical and chemical properties. Next, the concrete mix of M15 concrete was prepared and incorporated SCBA as a supplementary cementing material ranging from 0%, 5%, 10%, 15% and 20% by weight cement. Additionally, concrete containing SCBA as a partial cement substitute was subjected to elevated temperatures of 400°C, 600°C, and 800°C for exposure period of one hour. The residual compressive strength was assessed and compared with the reference concrete at room temperature. The findings indicate that at room temperature, the compressive strength of concrete increased with SCBA incorporation up to 10%. Even at a 15% cement substitution, the strength remained comparable to that of the control mix. While a consistent decline in compressive strength was observed at higher temperatures, the inclusion of SCBA slightly reduced this deterioration. The reduction was less pronounced up to a 10% cement replacement. These results support the effectiveness of SCBA as a supplementary cementing material in improving concrete performance under elevated temperature conditions.

KEYWORDS: Sugarcane Bagasse Ash, Cement, Concrete, Elevated Temperatures, Compressive Strength.

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COMPRESSIVE STRENGTH OF CONCRETE USING BRICK AGGREGATE AS A REPLACEMENT FOR NATURAL AGGREGATE

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ABSTRACT: In the contemporary era, concrete has become the most popular construction material. Modern industries greatly utilize the material and have produced various beautiful, eye-catching and amazing structures. The most commonly used coarse aggregate in concrete is obtained from different types of rocks. However, the type of rocks suitable for concrete is not available everywhere. This research was conducted to estimate the compressive strength of concrete by replacing coarse aggregate with aggregate obtained from bricks. The brick aggregate was utilized in the concrete ranging from 0% to 100% at the difference of 20%. Utilization of brick aggregate in concrete not only reduced the weight of concrete but also resulted in the reduction of self-weight of the concrete specimen. From the results, it was found that the average reduction in the compressive strength of concrete was 13.5%. While with the overall 100% replacement, there was a reduction of 22%. To conclude, it was found that brick aggregate can be used as an alternative of natural aggregate.

KEYWORDS: Concrete, Natural Aggregate, Brick Aggregate, Compressive Strength, Self-Weight.

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SEISMIC AND STRUCTURAL PERFORMANCE EVALUATION OF A COMMERCIAL PLAZA USING COMPUTATIONAL AND MANUAL METHODS

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ABSTRACT: This paper presents the comprehensive analysis and design of a G+4 commercial plaza with dimensions of 45x90 ft², integrating advanced structural engineering software for accuracy and efficiency. The architectural layout was developed using AutoCAD and Revit, ensuring a functional and aesthetically optimized design. Structural analysis was performed in ETABS, considering gravity, wind, and seismic loads as per ASCE 7-16 standards. The study evaluated material properties, reinforcement detailing, and load distributions, demonstrating structural stability. The beam design was assessed using both ETABS and manual calculations, confirming structural components meet safety and serviceability criteria. The findings contribute to the efficient and optimized design of mid-rise commercial buildings, ensuring structural integrity and resilience against environmental and seismic forces. The study emphasizes the importance of integrating software-based analysis with manual verification to enhance design reliability and accuracy.

KEYWORDS: ETABS, Seismic Loads, Comprehensive analysis and ASCE 7-16

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UTILIZATION OF SUGARCANE BAGASSE ASH AND RISE HUSK ASH AS CEMENT REPLACEMENT MATERIAL IN CONCRETE AT ELEVATED TEMPERATURE

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ABSTRACT: With growing concerns about the environment and the depletion of natural resources in cement production, finding sustainable alternatives is more important than ever. This study explores the use of sugarcane bagasse ash (SCBA) and rice husk ash (RHA) as partial replacements for cement in concrete, particularly examining their performance at high temperatures. Both SCBA and RHA are rich in silica and have pozzolanic properties, making them promising supplementary materials. The research assesses workability, compressive strength under normal and elevated temperatures, and overall durability. By optimizing the proportion of these materials, the study aims to improve fire resistance, lower carbon emissions, and support eco-friendly construction. The expected results include stronger mechanical properties and a greener alternative to traditional concrete.

KEYWORDS: Sustainable Construction, Pozzolanic Material, Cement Replacement, Fire Resistance, Carbon Emission Reduction.

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EVALUATING THE POTENTIAL OF HEMPCRETE FOR SUSTAINABLE GREEN BUILDING

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ABSTRACT: Hempcrete is an eco-friendly construction material composed of hemp fibers lime and water. During its curing process, it actively absorbs carbon dioxide, thereby mitigating greenhouse gas emissions. This bio-composite offers excellent thermal insulation, maintaining comfortable indoor temperatures across seasons without emitting harmful chemicals. Its versatile applications include use in walls, floors, and roofs, contributing to improved energy efficiency and healthier living environments. Despite challenges such as limited hemp supply and evolving building regulations, the rapid growth rate of hemp maturing in approximately 100 days and its capacity to absorb significantly more carbon dioxide than traditional vegetation underscores its promising potential for sustainable construction.

KEYWORDS: Hempcrete, hemp fibre Concrete, sustainable construction, Eco-friendly Construction, Green Building, Energy Efficiency, Renewable Building Material, Carbon Negative.

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IMPROVEMENT OF SUBGRADE SOIL BY BLENDING TYRE DRIVEN AGGREGATE

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ABSTRACT: Waste production is increasing in developing countries like Pakistan due to rapid population growth. The waste product is transported to dumpsites, endangering the health of people and the environment. As a result, reusing this waste product is almost essential. Consumption in roads and other infrastructures is a better way to use a portion of this wastefulness, including crumb rubber. The inherent variability of soil nature, which can change in type and condition, significantly impacts pavements. The resistance to deformation under stress, which can be quantified in strength and stiffness, is a defining characteristic of subgrade soils. The subgrade strength of the soil is a critical aspect in ensuring the pavement's long-term viability and is regarded as crucial in pavement design. If pavements are built on unstable subgrade soils, they are vulnerable to settlement and potential pavement failure. This research aims to use scrap tyre driven aggregates to increase the bearing pressure of existing subgrade soil. The California Bearing Ratio (CBR) experiments were carried out on existing subgrade soil and improved soil with 5%, 15%, and 30% tyre driven aggregate replacement. At an optimum moisture level of 21.26 %, the maximum dry density of soil was 1636 kg/m3. The existing ground's CBR was found to be 3.90 %. When subgrade grade soil was replaced with 5%, 15%, and 30% demolished aggregates, the CBR value increased by 5.1%, 10%, and 28.7% of the existing value.

KEYWORDS: Subgrade, Tyre Derivative Aggregates, California Bearing Ratio.

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STRENGTH EVALUATION OF CONCRETE USING NANO SILICA AS PARTIAL REPLACEMENT OF CEMENT

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ABSTRACT: The use of nanotechnology in concrete has given the endeavors to enhance its qualities a new angle. Due to their extremely small particle size, nanomaterials can change the microstructure of concrete, affecting its properties. This research focuses on using 7nm-sized Nano silica to increase concrete's compressive strength and workability. A test was conducted by substituting cement with nano silica that was 0.4%, 0.8%, and 1.2% by weight. According to the tests done on it, the early-age compressive strength of the concrete has increased significantly, while the overall compressive strength has only slightly increased. With an increase in the amount of nano silica, both strength and workability rose significantly. The optimum replacement proportion of nano silica at which the strength of concrete rose highly was observed to be 1.2%.

KEYWORDS: Cement, Concrete, Compressive Strength, Nano-Silica, Workability.

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ANALYZING FIRE INCIDENTS IN KARACHI: CAUSES, CONSEQUENCES, AND SOLUTIONS

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ABSTRACT: As the fire incident cases are increasing in the metropolitan city Karachi. Overcrowded streets, crumbling infrastructure, and scarce resources make the city a fire hazard. This paper dives deep into Karachi's specific vulnerabilities, from electrical hazards in crowded markets to illegal construction practices in towering high-rises with limited firefighting stations. The study analyzed major fire incidents which not only life losses such as the Baldia Town textile factory fire over 300 casualties and property damages like the Cooperative Market fire causing millions in damages, highlighting the devastating consequences. Through extensive data analysis of a recent fire in a major shopping center, the study uncovers critical issues related to electrical protocols and slow response times due to traffic congestion, communication breakdowns, and inadequate fire safety protocols. Furthermore, the research examined the current state of Karachi's fire sector, including the capabilities and distribution of its firefighting stations. Analyzing data from the past three years, the study pinpoints high-risk areas and propose actionable strategies to reduce fire incidents and mitigate damage. The study identified limitations in Karachi's firefighting stations, which were compared to the city's building code overseen by the KMC building authority. Based on an intensive analysis of various factors, including population density, the research recommends the construction of new stations strategically located to meet established standards. Additionally, it proposes upgrades to existing facilities to enhance their firefighting capabilities.

KEYWORDS: Fire Incidents, Fire Sector, Fire Stations, Karachi, Urban Fire Safety.

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3D NUMERICAL MODELLING OF FOUNDATION BEHVIOUR IN WATERLOGGED GROUND

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ABSTRACT: Construction on a waterlogged ground has been a challenging for a geotechnical engineer. Construction of buildings over waterlogged sites can be a problem due to low bearing capacity, high water table level and post-construction and consolidation settlements may damage the buildings. The objectives of this study are to find out settlement behavior of foundation and suggest suitable type of foundations that can sustain building loads safely. To achieve these objectives, three-dimensional coupled consolidation analyses were carried out to determine the bearing capacities of the shallow footings of sizes (1.22×1.22 m^2), (1.83×1.83 m^2). It was found that the computed ultimate load for the footing of sizes (1.22×1.22 m^2), (1.83×1.83 m^2) on waterlogged area were estimated to be 10 kN and 21 kN, respectively. The bearing capacity of the footing can be improved by filling material (i.e. pit sand) on waterlogged areas. The bearing capacities of the footing of sizes (1.22×1.22 m^2) and (1.83×1.83 m^2) constructed on pit sand increased by 800% and 500%, respectively. Alternative types of the foundations in the waterlogged ground were suggested to get higher bearing capacity. The types of foundations are raft, single pile, pile group and piled raft. The ultimate load carrying capacity of single pile was computed as 300 kN which is significantly higher than that of shallow footings. The ultimate load carrying capacity of (2×2) pile group was computed as 400 kN. The ultimate load carrying capacity of piled raft was computed as 620 kN.

KEYWORDS: Waterlogged Ground, geotechnical, load carrying capacity, pit sand.

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ASSESSMENT OF THE MECHANICAL PROPERTIES OF ASPHALT PAVEMENT ENHANCED WITH POLYPROPYLENE FIBER REINFORCEMENT FOR SUPERIOR LONGEVITY

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ABSTRACT: The performance and durability of asphalt mixtures are critical for sustainable road construction. This study examines the impact of incorporating polypropylene (PP) fibers into asphalt mixtures, focusing on Marshall Characteristics such as stability, flow, bulk density, voids in the mix, and voids filled with bitumen. Various PP fiber compositions were introduced into the asphalt mix to assess mechanical performance. Experimental results demonstrated that adding PP fibers significantly improved the stability and stiffness of the mixture while reducing deformation and enhancing resistance to cracking. The optimized air void content contributed to better compaction and load-bearing capacity, ultimately increasing the pavement's longevity. Additionally, the fiber reinforcement improved fatigue resistance, ensuring better durability under repeated traffic loads. By enhancing structural integrity and performance, PP fiber-reinforced asphalt presents a viable solution for long-lasting pavement. This study underscores the effectiveness of PP fibers in improving asphalt properties, offering a promising approach to developing more resilient and sustainable road surfaces. The findings suggest that incorporating PP fibers can lead to reduced maintenance costs and extended service life, making them a valuable addition to modern road construction techniques.

KEYWORDS: Polypropylene fiber, asphalt mix, Marshall Properties, stability, durability.

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ENHANCING TEAM EFFICIENCY IN BIM: A COMPARATIVE STUDY OF CLOUD AND LOCAL WORKSHARING IN REVIT

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ABSTRACT: As Building Information Modeling (BIM) continues to evolve in the Architecture, Engineering, and Construction (AEC) industry, efficient worksharing has become a key factor in project success. However, AEC firms have difficulties in choosing the best worksharing solution because of data security issues, file corruption threats, performance irregularities, and remote accessibility problems. Autodesk Revit offers two primary worksharing approaches i.e. Cloud-Based Worksharing (BIM 360/Autodesk Construction Cloud - ACC) and Local Worksharing (LAN-based central models). The lack of a clear framework for choosing between these options leads to inefficiencies, costly rework, and project delays. This paper compares these methods by analyzing synchronization speed, model integrity, file corruption risks, collaboration efficiency, and data security. Using a case study approach, the research evaluates real-world projects to provide AEC firms with a structured strategy for optimizing their worksharing processes. The results identify that Local Worksharing has greater speed and reliability in the office environment but poses risks of corruption of files and restrictions in remote access. Whereas Cloud-Based Worksharing has more collaboration for distributed teams and more protection of files but has inherent latency issues and recurring fees for subscription. The findings offer that worksharing decisions must be made by companies based on project complexity, team allocation, and IT infrastructure. Local worksharing in combination with cloud worksharing may offer the balance of approach that is ideal. Advances in AI-based automation and forecast analysis in the future will further build on BIM processes to offer more efficiency and responsiveness for professionals in the AEC industry.

KEYWORDS: Building Information Modeling, BIM worksharing, cloud-based collaboration, local worksharing, Autodesk Revit, data security, synchronization speed, project efficiency, AEC industry, AI-driven BIM.

Ref: 1st ICSIID//KHP/71

EXAMINING THE EFFECT ON LIGHTWEIGHT CONCRETE (LWC) BY PARTIALLY REPLACING FINE AGGREGATE WITH CRUMB RUBBER AND CEMENT WITH SUGARCANE BAGASSE ASH (SCBA)

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ABSTRACT: Concrete is widely used as a major construction material in the world. However, its high density has always been a challenge for engineers. Aggregates used in concrete provide material strength but also significantly increase their weight. Another ingredient in concrete making is cement, an artificial binding agent that generates hazardous carbon dioxide during manufacturing, impacting both the environment and human health. Waste disposal has also become a challenge in Pakistan. Considering these issues, this research paper explores the use of 30% crumb rubber (CR) as an aggregate substitute to prepare lightweight concrete (LWC) with sugarcane bagasse ash (SCBA) with different proportions as a cement replacement to examine the impact of SCBA on the properties of LWC. The proportions of SCBA used in this research were 0%, 5%, and 10%. Concrete cubes of 150×150×150 mm were cast and cured at 7 and 28 days. Slump, Water absorption, Density, and Compressive strength were determined. The water absorption of the LWC with 5% of SCBA was less after 28 days of curing, which corresponds to its higher density. However, the compressive strength of LWC, with 10% SCBA exhibited greater values than other samples.

KEYWORDS: Lightweight concrete, crumb rubber, Sugarcane bagasse ash, compressive strength, ASTM

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THE USE OF SMART BUILDING MATERIALS IN CONSTRUCTION FOR THE CLIMATE RESILIENCE

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ABSTRACT: The built environment is vulnerable to climate-related disasters, demanding innovative construction materials that enhance resilience. This study explores the potential of smart building materials like rice husk ask (RHA) and sugarcane bagasse ash (SCBA) in mitigating climate-related risks. This study investigated the properties and applications of concrete containing different percentage of RHA and SCBA as phase change materials. Results show that these materials can significantly reduce consumption of ordinary Portland cement (OPC), improve strength and durability aspects of the concrete. This study declared that RHA and SCBA could extensively help in meeting with the climate resilience parameters as these help in increasing workability, compressive strength and tensile strength of material. Therefore, smart building materials are the future of the construction industry so as to provide climate resilience in the structures.

KEYWORDS: Smart Building Materials, Climate Resilience, Sustainable Construction, Strength and Durability.

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EFFECT OF MARBLE POWDER ON THE STRENGTH OF CONCRETE

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ABSTRACT: This paper aims to create a concrete mix by partially replacing cement with marble powder to evaluate its impact on compressive strength. To achieve this, an experimental program was designed that involved casting, curing, and testing cube specimens. The tests were conducted at 7 and 28 days, using various replacement levels of 5%, 10%, 15%, and 20% marble powder, alongside a control mix without any substitution. After detailed study, it was concluded that the compressive strength increases by replacing 5% and 10% of cement with marble powder, and decreases beyond 10%.

KEYWORDS: Concrete, Marble Powder, Compressive Strength, Cubes, Cement, Replacement.

Ref: 1st ICSIID//KHP/74

IMPACT OF FLOOD HAZARD AND LOSSES ON QUALITY OF LIFE: A CASE STUDY OF DERA GHAZI KHAN

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ABSTRACT: Due to the rapid increase in climate change, the frequency of floods and other disasters is increasing. Pakistan is among the most vulnerable and affected countries. It does not only cause immediate damage to the physical infrastructure but leaves many other devastating impacts on the affected ones. Many research studies have been carried out to evaluate the physical and economic damages. This study is more focused on the non-monetary damages and their impacts in the long run. The study aims to evaluate the pre and post-flood quality of life in flood-prone areas of the country. Quality of life (QoL) is a broad social, mental, and physical concept. Data was collected from both Urban and Rural areas of Dera Ghazi Khan. A total of 399 samples were collected via household surveys. The study carries out a multi-dimensional analysis of floods on quality of life (QOL), comprising physical, social, and mental well-being. The study found that social losses and hazards influenced the quality of life of the exposed population. The research consists of four key objectives. We aim to comprehensively understand the post-flood effects in addressing multifaceted disaster issues and propose practical guidelines for its incorporation into urban planning processes.

KEYWORDS: climate change, disaster management, floods, Quality of Life, mental well-being

Ref: 1st ICSIID//KHP/75

EFFECTS OF WASTE BOTTLE CAPS ON THE PROPERTIES OF CONCRETE

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ABSTRACT: This study aims to utilize Waste Bottle Caps (WBC) in concrete to solve the paste waste issue. Considering the environmental issue, the WBC considered as an additive fiber in concrete. This study considered caps of soft drink bottles which were cut in to two and four pieces to achieve aspect ratio (L/D) of 2 and 4. The different percentage pf WBC were used in this study such as 0.5, 1.0, 1.5, and 2% with reference to cement weight. It was found that WBC affected the workability, density, compressive, and splitting tensile strengths of concrete. It was also observed that the workability of concrete decreases as the percentage of WBC increases, the workability decreases by using both aspect ratios, but it was observed that the workability greatly decreased with aspect ratio 2 in the comparison of aspect ratio 4. The experimental results indicated that the density, compressive and splitting tensile strength of concrete decreases with increases the percentage of WBC in concrete but it was also observed that the compressive and splitting tensile strength more decreases with aspect ratio 4 in comparison of aspect ratio 2. This study concluded that 0.5% dose of WBC as fiber with aspect ratio 2 is recommended as optimum percentage which gives lower reduction in the compressive and splitting tensile strength of concrete.

KEYWORDS: Concrete, Waste Bottle Caps, Workability, Density, Compressive Strength, Splitting Tensile Strength.

Ref: 1st ICSIID//KHP/77

ANALYSIS & DESIGN OF 14-STORY PLAZA WITH SHEAR WALLS USING ETABS

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ABSTRACT: Pakistan is a developing country, and the construction of high-rise buildings is required to increase vertical growth due to the limited availability of land. However, with the vertical growth, most of the area of the building is taken by the large columns, making it unpleasant and uneconomical for the stakeholders. So, for providing more space and reduction in dimensions of columns, and for resisting lateral loads acting on the structure, the concept of a shear wall originated. Nowadays shear walls is a developing item or say an important feature of High-rise buildings. On the other hand, lateral forces make instability in the structure which causes the collapse of the structure, as it is observed from the research that vertical loading doesn't create any impact on the structure with shear wall, but the lateral force causes the failure of the structure. The basic lateral loads impacting the structure are earthquake and wind loads. However, if the structure is designed by taking each factor into account which leads towards the failure, and strengthening them by some shear and bracing techniques, so there is no quite rare chance of the failure of the structure. The aim of this research is to investigate the response of a high-rise building with shear walls during seismic excitations by using software ETABS. The building selected is proposed for this research work and, it is a reinforced concrete building having shear walls at different places and positions. The building is to be analyzed and designed for different loads i.e., Dead, Live, Super Imposed Dead Load and Earthquake Loads The research method includes the linear static analysis also known as pushover analysis. The required data has been extracted from Building code of Pakistan and ASCE 7-16, various displacement and drift values for different floors will be observed. The results are observed and analyzed, and the outcomes meet with the general requirement of a structure. Hence structure is safe against earthquake lateral loads. The building is analyzed and design for different loads i.e., Dead, Live, Earthquake Loads where the maximum values of shear force and bending moment diagrams were due to the Dead and Live Loads. To conclude, the proposed building with shear walls is safe under seismic excitation.

KEYWORDS: High-rise, ETABS, Structure, Model, Seismic zone, Drift

Ref: 1st ICSIID//KHP/78

IMPACT OF SUGARCANE BAGASSE ASH AS A CEMENTITIOUS MATERIAL ON CONCRETE STRENGTH AND DURABILITY UNDER ACIDIC CONDITIONS

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ABSTRACT: The incorporation of supplementary cementitious materials (SCMs) in concrete production is gaining attention for its environmental benefits and sustainability. This study evaluates the effect of sugarcane bagasse ash (SCBA) as a partial cement replacement on the strength and durability of concrete, particularly under acid exposure. Cement was replaced with SCBA at 10%, 20%, and 30%, and specimens were cured in normal water for 28 days before exposure to sulphuric acid ($H_2 SO_4$) for 7, 28, 56, and 90 days. Compressive strength, water absorption, and resistance to acid attacks were analyzed to assess durability. Results indicate that SCBA enhances long-term strength due to pozzolanic activity, with optimal performance observed at 10% replacement. Additionally, SCBA-modified concrete demonstrated improved resistance to acid attacks, reducing mass loss and strength deterioration compared to conventional concrete. These findings highlight SCBA's potential as a sustainable cement alternative, offering enhanced mechanical properties and durability while contributing to reduced cement consumption and lower environmental impact. This study supports the development of eco-friendly concrete solutions for sustainable construction practices.

KEYWORDS: Sugarcane Bagasse Ash, Waste Disposal, Structural Concrete, Pozzolanic Activity, Durability.

Ref: 1st ICSIID//KHP/79

EVALUATION OF THE USE OF RECYCLED PLASTIC FOR THE DEVELOPMENT OF TRAFFIC CONTROL DEVICES

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ABSTRACT: Plastic waste poses a significant environmental challenge, necessitating innovative solutions for its management and repurposing. Traditional road safety devices, such as cones and barricades, are often made from rubber, metal, or concrete, leading to high costs, longer manufacturing times, and environmental impact. The Pakistan Plastic Pact (PPP) promotes plastic waste reduction and supports circular economy models, fostering initiatives that transform waste into valuable resources. In this study the results of the two types of traffic control devices; traffic cones and traffic barriers, made from waste plastic bottles are presented. Parameters such as type of raw materials, manufacturing time and manufacturing cost are discussed. This research and development exercise found that waste plastic bottles can easily be utilized in making various traffic control devices, thus, creating a sustainable system for plastic waste management. Repurposing recycled plastic for traffic safety devices presents a cost-effective and durable alternative, as it is lightweight, weather-resistant, and reduces transportation costs while extending product lifespan. Additionally, plastic-based safety equipment can be manufactured more quickly and at lower costs, ensuring rapid deployment in high-traffic urban areas. With continued innovation and policy support, integrating recycled plastic into Karachi's traffic management system can enhance economic efficiency, environmental sustainability, and long-term resilience in urban infrastructure.

KEYWORDS: Waste plastic bottle, Traffic cone, Traffic barrier, low-cost device, sustainable.

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STRENGTH EVALUATION OF CONCRETE CONTAINING SUGARCANE BAGASSE ASH AS A PARTIAL CEMENT REPLACEMENT

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ABSTRACT: The increasing demand for sustainable construction materials has led to the exploration of alternative cementitious materials. This study investigates the incorporation of Sugarcane Bagasse Ash (SCBA) as a partial replacement for cement in concrete at 0,5,10 and 15%. SCBA, an agricultural byproduct, offers environmental and economic benefits, particularly in regions with abundant sugarcane production. The focus of this research was to evaluate the workability and compressive strength test of concrete mixes containing varying proportions of SCBA. The workability of concrete was checked by adding SCBA, ranging from 5 to 15%, to assess the impact of SCBA on the consistency, ease of handling, and flowability of the fresh concrete mix. Additionally, a compressive strength test was also performed on cured concrete specimens to evaluate the material's mechanical properties. The results of these tests concluded that the use of 5% SCBA in concrete could provide appropriate results for structural applications of concrete.

KEYWORDS: Sugarcane Bagasse Ash, Concrete, Workability, Compressive Strength, Mechanical Properties

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SUSTAINABLE INFRASTRUCTURE FOR PAKISTAN USING INTEGRATED GREEN TECHNOLOGIES: A MULTIDISCIPLINARY APPROACH

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ABSTRACT: The development of sustainable infrastructure is important for reducing climate change, mitigating environmental impacts, and promoting human well-being. This paper presents a multidisciplinary approach to sustainable infrastructure development, integrating green technologies from both Civil and Mechanical engineering disciplines. A case study if net-zero energy building that includes solar photovoltaic panels, green roof systems, and advanced mechanical systems is used to illustrate the framework. A proposed framework presents combining Building Information Modelling (BIM) with energy simulation and life cycle assessment (LCA) to optimize the design and operation of sustainable infrastructure systems. The results explained that the integrated strategy can improve indoor air quality and occupant comfort while achieving notable reduction in energy usage approximately 40%, decrease 60% in greenhouse gas emissions, and environmental effects. The potential of integrated green technology to revolutionize the built environment and advance sustainable development is highlighted in the paper'¢ conclusion.

KEYWORDS: Sustainable infrastructure, Photovoltaic panels, Building Information Modeling, Life cycle assessment, Greenhouse.

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TO MEASURING THE EFFECTS OF SELF-SENSING CONCRETE IN MODERN INFRASTRUCTURE

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ABSTRACT: Self-sensing concrete (SSC) is a special type of concrete that can measure its own condition and detect changes in the environment. As concrete technology advanced, several novel types of concrete have developed as well as SSC. SSC can monitor itself to determine its condition and find out changes in environmental parameters. The types of SSC most closely affect the sense ability of the materials as functional fillers such as steel fibers, carbon black and steel slag. SSC is divided into two classes. They are intrinsic and non-intrinsic. The main application of each category is explained in this paper. Particular attention is given to the applications of intrinsic SSC in structural health monitoring and traffic detection. The self-sensing property of concrete is achieved by the concrete's piezoresistive behavior, i.e. electrical resistance changes with mechanical stress (or with deformation).

KEYWORDS: intrinsic, non-intrinsic smart concrete, conductive materials, carbon fibers & nanotubes, strain, stress, cracks, piezoresistive behavior, network, electrical resistance

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SUSTAINABLE STRATEGIES FOR HOSPITAL WASTE MANAGEMENT: A CASE STUDY OF CIVIL HOSPITAL KHAIRPUR MIR'S

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ABSTRACT: Hospital waste management (HWM) is a critical public health and environmental issue, particularly in resource-constrained settings. This study investigates the current hospital waste management practices at Civil Hospital Khairpur Mir's, Pakistan, aiming to identify inefficiencies, assess existing barriers, and propose sustainable, actionable solutions. The hospital generates an average of 146 kg of waste per day, equating to a waste generation rate of 0.324 kg/bed/day. Of this, 70% is general waste, and 30% is hazardous, including sharps, pathological waste, and pharmaceutical residues. Despite regulatory frameworks like the Sindh Hospital Waste Management Rules 2014, the study finds that waste segregation practices are insufficient, with 86% of departments failing to adequately separate hazardous from non-hazardous materials. This results in cross-contamination, escalated treatment costs, and increased environmental risks. Through a mixed-methods approach comprising quantitative surveys, qualitative interviews, and direct observational analysis, this research uncovers critical operational shortcomings: lack of infrastructure, inadequate staff training, and insufficient budget allocations for waste management. The findings suggest that, while regulations exist, implementation is fragmented and inconsistent across departments. To address these gaps, the study proposes a comprehensive overhaul of the hospital's waste management system, emphasizing the adoption of color-coded bin systems in line with WHO guidelines, the integration of modern waste tracking technologies such as RFID and smart bins, and the utilization of waste-to-energy systems for non-recyclable waste.

Additionally, the research underscores the need for continuous staff education, the establishment of a robust waste management policy, and investment in essential infrastructure like sealed storage units and dedicated transport vehicles. By embracing these strategies, Civil Hospital Khairpur Mir's can significantly reduce health and environmental risks, enhance operational efficiency, and align with global best practices in sustainable hospital waste management. This study provides a practical roadmap for healthcare facilities in developing regions to enhance waste management while contributing to broader environmental sustainability goals.

KEYWORDS: Environmental Sustainability, Healthcare Waste, Public Health, Sustainable Waste Management, WHO Guidelines

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BENEFITSOF SURFACE IRRIGATION OPTIMIZATION IN THE PROJECT AREA OF NAI GAJ DAM

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ABSTRACT: This research focuses on the Nai Gaj Reservoir project to estimate yield projections for various crops in the region. Data was collected through farmer interviews using designed questionnaires and supplemented with secondary data from NESPAK and other relevant sources. The data was analyzed to simulate reservoir operations and optimize irrigation water allowances for different cropping patterns. Key factors such as crop production in arid and irrigated regions, crop production index, and available water discharge were used for yield forecasting. Irrigation performance and efficiencies—including application efficiency, storage and requirement efficiencies, and field distribution uniformity—were evaluated to improve surface irrigation, which is predominantly practiced in the area. Cropping patterns were designed considering climatic conditions, crop evapotranspiration, and regional cropping intensity. Results indicated that the total available water per year was 131,600 acre-feet, while crop water needs were estimated at 131,460 acre-feet using the CROPWAT model, accounting for irrigation losses. This confirms that the available water supply is sufficient for all cropping patterns. Additionally, optimizing surface irrigation could reduce water losses by 15–20%, allowing for beneficial use in hydropower generation, ultimately increasing crop production and improving farmers' prosperity in the region.

KEYWORDS: Nai Gaj Reservoir, Irrigation Optimization, Crop Yield Projection, Water Management, Surface Irrigation Efficiency.

Ref: 1st ICSIID//KHP/87

SUSTAINABLE CONCRETE SOLUTIONS: THE ROLE OF RICE HUSK ASH IN REDUCING CEMENT USAGE AND ENVIRONMENTAL IMPACT

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ABSTRACT: The construction industry is a major contributor to environmental degradation, primarily due to the large-scale production of Portland cement, which releases substantial amounts of carbon dioxide into the atmosphere. This research investigates the potential of using Rice Husk Ash (RHA) as a partial replacement for cement in concrete to enhance sustainability and reduce the environmental impact of construction. The study explores the effects of varying percentages of RHA (5%, 10%, 15%, and 20%) on the mechanical properties of concrete, including compressive strength, workability, and durability. Concrete samples were prepared by replacing cement with RHA and tested at 7, 14, and 28 days of curing. The results indicate that the incorporation of RHA improves the workability of the concrete mix, while the compressive strength generally increases at lower replacement levels (5% and 10%), but decreases at higher replacement levels (15% and 20%). Furthermore, the study reveals that RHA concrete demonstrates satisfactory durability properties, including enhanced resistance to water absorption and chemical attacks. The findings suggest that the partial replacement of cement with RHA provides a viable solution for sustainable concrete production and contributes to the reduction of agricultural waste. The study concludes that up to 10% replacement of cement with rice husk ash could be optimal for achieving a balance between environmental benefits and maintaining adequate concrete strength and durability.

Keywords: RHA, Sustainable Concrete, Cement Replacement, Compressive Strength, Environmental Impact

ICSIID Key Takeaways

Category	Topic	Key Takeaways	Ref.
Sustainable Materials	**Fired Clay Bricks vs. Interlocking Earth Blocks**	Interlocking blocks resist aggressive environments better due to mortarless design.	KHP/01
	Thermal Block Insulation	Composite masonry blocks reduce cooling/heating loads by 3–5°C with 55% lower thermal conductivity.	KHP/06
	Steel Scale Waste in Concrete	Partial replacement of fine aggregates improves sustainability without compromising strength.	KHP/09
	Sugarcane Bagasse Ash (SCBA) Concrete	10% SCBA replacement enhances durability under high temperatures.	KHP/56
	Rice Husk Ash (RHA) Concrete	Optimal at 10% cement replacement, balancing strength and CO_2 reduction.	KHP/87
	Geopolymer Concrete	Fly ash-based mix achieves 58.5 MPa strength, eliminating Portland cement.	KHP/24
	Lightweight Concrete with Pumice	20% pumice replacement optimizes workability and reduces density.	KHP/33
	Recycled Waste Glass Concrete	100% fine aggregate replacement increases strength by 25.6%.	KHP/40
	Bamboo Fiber Concrete	Fiber spacing theory predicts tensile strength accurately (<5% error).	KHP/41
	Plastic-Modified Asphalt	Polypropylene fibers improve pavement longevity and crack resistance.	KHP/69
	Hempcrete	Carbon-negative material with superior thermal insulation.	KHP/60
	Metakaolin from Indigenous Soorh	15% cement replacement enhances concrete properties.	KHP/13
Circular Economy & IBS	**Industrialized Building Systems (IBS)**	Prefabrication + circular economy reduces waste and foreign tech dependency.	KHP/02
	Modular Amphibious Housing	Light-gauge steel structures adapt to floods in Sindh/Punjab.	KHP/17
	C&D Waste Bricks	Fly ash + demolition waste bricks achieve 20.84 MPa strength.	KHP/54
	Solar PV Recycling	Policy gaps hinder large-scale adoption; AI-assisted sorting proposed.	KHP/52
Climate Resilience	**Cooling Bricks from Coal Ash**	75% bottom ash mix reduces urban heat via evaporative cooling.	KHP/03
	Flood Risk Communication	Non-structural measures (e.g., early warnings) enhance Swat Valley resilience.	KHP/34

	Urban Adaptation Planning	Islamabad communities use micro/meso strategies over macro (NbS).	KHP/11
	Smart Traffic Management	ML + image processing reduce congestion in Karachi.	KHP/43
AI & Advanced Tech	**AI in Civil Engineering**	Indigenous AI solutions monitor construction progress and structural health.	KHP/84
	3D Concrete Printing	Nozzle standoff distance critical for print quality/flexural strength.	KHP/32
	BIM Adoption in Pakistan	Lack of skilled workforce and policies are top barriers.	KHP/48
	Automated Rebar Detailing	Dynamo scripting cuts modeling time by 60%.	KHP/50
	Self-Sensing Concrete	Piezoresistive behavior enables crack/strain detection.	KHP/82
Waste & Recycling	**Jhama Brick Aggregates**	20–25% replacement optimizes cost and lightweight properties.	KHP/51
	EPS Waste in Pavements	Acetone-treated EPS aggregates reduce concrete density by 24.5%.	KHP/45
	Waste Bottle Cap Concrete	0.5% addition with aspect ratio 2 minimizes strength loss.	KHP/75
	Recycled Plastic Traffic Devices	Low-cost cones/barricades from bottles align with circular economy.	KHP/79
Structural Engineering	**Steel Plate Girders (FEM Analysis)**	Thicker plates improve buckling resistance; FEM reduces testing costs.	KHP/14
	Shear Walls in High-Rises	ETABS analysis confirms seismic safety for 14-story plazas.	KHP/77
	Foundation in Waterlogged Ground	Piled rafts increase bearing capacity by 620% vs. shallow footings.	KHP/64
Urban & Social Impact	**Karachi Fire Incidents**	Electrical hazards + slow response due to traffic congestion are critical risks.	KHP/63
	Muslim Architecture in Multan	Large shrines have better infrastructure than small, neglected ones.	KHP/19
	QoL Post-Floods (Dera Ghazi Khan)	Social/mental well-being declines significantly after disasters.	KHP/74
	Hospital Waste Management	86% departments fail at segregation; RFID tracking proposed.	KHP/83
Policy & Economics	**Green Mobility in Karachi**	EVs + solar charging need subsidies and grid stability.	KHP/07
	Affordable Housing Standards	Rigid infrastructure regulations inflate costs; context-specific reforms urged.	KHP/15
	Nai Gaj Dam Irrigation	Optimized surface irrigation saves 15–20% water for hydropower.	KHP/86

Full Length Submissions

Subject: Structural and Geotechnical Engineering

Theme: Sustainable and Resilient Structural Systems

Ref: 1st ICSIID//KHP/16

Mechanical properties of rubberized engineering cementitious composites reinforced with hybrid textile fibers

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ABSTRACT
Engineered Cementitious Composites (ECC) are highly regarded in the construction industry for their superior strength, ductility, and low permeability compared to traditional concrete. However, the extensive use of natural sand in ECC production raises concerns about resource depletion, while the growing disposal of waste tires presents significant environmental challenges. This study proposes a novel solution by partially replacing natural sand with waste rubber powder and incorporating textile waste fibres to enhance ECC's mechanical properties, addressing both resource conservation and waste management issues. ECC samples were prepared with varying percentages of crumb rubber (10%, 20%, and 30%) and a fixed 2% textile fibre content. These samples underwent rigorous mechanical testing, including compressive, splitting tensile, and flexural strength evaluations. The results demonstrated that the modified ECC achieved a compressive strength of 36.34 MPa, a tensile strength of 10.402 MPa, and a flexural strength of 7.48 MPa, indicating improved performance over conventional ECC. This research highlights the potential of utilizing waste materials, such as crumb rubber and textile fibres, to develop sustainable construction materials without compromising mechanical properties, offering an environmentally friendly alternative that reduces reliance on natural sand, repurposes industrial and textile waste, and advances sustainable material innovation while promoting resource efficiency and addressing critical waste disposal challenges.

Keywords: Crumb rubber, engineered cementitious composite, mechanical properties and textile fibres

1. Introduction

Engineered Cementitious Composites (ECC) have become a fundamental component of modern engineering practices due to their exceptional durability and superior mechanical properties [1]. However, a significant challenge that may compromise the durability and safety of structures is their susceptibility to cracking [2]. Addressing this inherent limitation has become a primary focus for engineering professionals, driving extensive research into the development of innovative materials and additives for ECC formulations to enhance toughness and crack resistance, as highlighted by previous studies [1, 2]. ECC is a composite material that combines cementitious components with carefully selected short, randomly distributed fibres, typically composed of polymers [1]. Often referred to as flexible concrete,

ECC is designed to exhibit higher elasticity and greater resistance to cracking compared to traditional concrete. In contrast to conventional concrete that is brittle and prone to sudden failure, ECC can undergo significant deformation while maintaining structural integrity. This remarkable behavior is achieved through the incorporation of specialized fibres that control crack propagation and limit crack widths, even under substantial stress [3-8]. The ductility of the material combined with its potential for enhancing the lifetime and strength of structures [9] has made ECC indispensable for critical applications such as bridges [10, 11], seismic-resisting buildings [11], or infrastructure renovations [12].

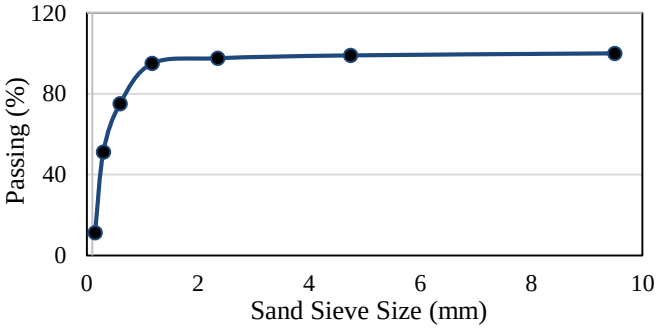
Synthetic fibres are polyvinyl alcohol (PVA) and polypropylene that have high strength and durability giving ECC its unique strain hardening as well as crack bridging properties [13, 14]. Even though natural fibres may be less robust and offer sustainability and eco-friendliness [15, 16]. Additionally, the utilisation of rice husks weighing 20 kg having low bulk densities ranging between 90 – 150 kg/m^3 improves mechanical properties [17]. While Zhang et al. [18] explored that adding jute fibre helps the matrix of cement to stick together more tightly. For optimum performance, the following conditions need to be met; water-cement ratio of 0.30, jute fibres with length 16±2 mm and fibre content 3.0 kg/m^3 by volume [18]. Jute fibers enhance the durability, sustainability, and freeze-thaw resistance of concrete structures in cold climates, offering an eco-friendly and renewable alternative to synthetic reinforcements while promoting longer-lasting and environmentally conscious construction practices [19-21]. Moreover, the hybrid fibre approach allows for optimization of fibre performance around different scales with short fibres [22] that resist micro-cracking while longer fibres reinforce larger cracks [23]. Thus, this combination of strength, toughness and durability makes hybrid textile fibres [24] an ideal reinforcement strategy for ECC within harsh structural applications because it ensures long-term performance. In construction industry artificial fibres are being incorporated in ECC. Nowadays, polyester fibres (PET) has rapidly increased its production capacity in the textile industry, resulting in a greater production of waste fibres, with an annual output of 22.67 billion tons. The characteristic of PET is that it has a tensile strength of 5%, but the elongation decreases as it is loaded [25].

ECC typically utilize approximately 50% natural sand in their composition, while global river sand extraction averages between 10,000 m^3/year and 230 million m^3/year. The excessive excavation of natural sand from riverbeds has significant environmental consequences, including channel destabilization, riverbed lowering, and a decline in the water table, which jeopardizes water availability for local communities, agriculture, and other essential activities [26]. Globally, millions of tires are discarded or buried annually, posing significant ecological threats. Approximately 1 billion tires reach the end of their service life each year, with 50% being sent to landfills or improperly disposed of as waste. If this trend continues, the number of discarded tires is projected to reach 5 billion by 2030 [27], highlighting the urgent need for sustainable waste management solutions [27]. A previous study [28] conducted a comprehensive study on rubberized concrete (RC), revealing significant findings regarding its performance. The analysis demonstrated that when the rubber content in RC exceeds 30% by volume, notable improvements are observed in mechanical strength, fire resistance, permeability, and freeze-thaw behavior, highlighting its potential as a durable and resilient construction material. Moreover, From the previous research [29] it is observed that the elastic modulus of ECC is relatively lower than that of conventional concrete, ranging from 30% to 50% due to the absence of course aggregate. The two critical factors are compressive strength and modules of ECC, both of which should be improved simultaneously while retaining proper ductility. In is worth note that the recent literature published on ECC [30, 31], certain limitations of the existing practices can be observed, especially in the absence of the standardization of design codes that curtails its broader use in the construction sector. While also acknowledging that there has been research on the mechanical properties of ECC. The ambition of this work is to bridge existing gaps by examining the impact of hybrid textile fibre reinforcement and varied waste rubber powder content on the mechanical performance of ECC. It has been noted in recent research that waste rubber was found to weaken concrete as it made use of concrete-rubber composite because the bond between the rubber and the cement was poorly established.

2. Materials and Methodology

2.1 Materials

The research utilized ordinary Portland cement (OPC) with a specific gravity of 3.16 and was used as the binding material in the ECC mix. The hill sand was used as fine aggregate and the specific gravity was observed to be 2.6, which had a water absorption of 1.01%. The sand aggregate had a fine modulus of 1.71, indicating a finer texture and uniform size. Rubber was used to partially replace sand. The rubber and sand were sieved by 30–40 mesh following ASTM-C128 standards. Rubber was obtained from a local supplier in Pakistan to replace sand in the ECC mix at varying percentages of 10, 20, and 30%. Two types of fibres were used for reinforcement: jute fibre and polyester fibre. The jute fibre had a



shrinkage of 7.27%, a length of 54 mm, moisture content of 0.38%, and a bulk density of 53.70 kg/m^3.

Figure 1. Particle size distribution of sand

a b c d e f

Figure 2. ECC mix (a) ordinary Portland cement, (b) sand, (c) rubber powder, (d) polyester fibre, (e) jute fibre and (f) workability

2.2 Mix proportion

This study investigated the mechanical properties such as flexural, tensile, and compressive strengths of rubberized ECC by partially replacing sand with rubber at varying percentages of 0%, 10%, 20%, and 30%. Hybrid fibres, comprising jute fibres and waste polyester textile fibres, were incorporated at a total content of 2%, with fibre ratios of 1:1 and 1.5:0.5. A water-to-cement (w/c) ratio of 0.42 was maintained throughout the study. Seven ECC mixtures were developed, each featuring different proportions of sand replacement with rubber and hybrid fibre reinforcement, as detailed in Table 2. The rubber content was varied at 10%, 20%, and 30%, replacing an equivalent portion of the sand while maintaining a consistent sand-to-cement ratio of 1:1, a water-binder ratio of 0.42, and total fibre content of 2%. The specimens were labelled using a nomenclature reflecting their rubber and fibre composition. For instance, "10CR-0.5PE" denotes a mixture containing 10% rubber, 0.5% polyester fibres, and 1.5% jute fibres, corresponding to a fibre ratio of 1.5:0.5.

Table 1. Mix Calculation

ECC							
Mix No.	Mix Name	Sand Replacement	Sand	Cement	Fibres		Water (kg/m^3)
		CR (Kg/m^3)	(Kg/m^3)	(Kg/m^3)	Jute fibres (Kg/m^3)	Polyester (Kg/m3)	
1	Control	0	750	750	0	0	315
2	10CR-0.5PE	75	675	750	11.25	3.75	315
3	10CR-1PE	67.5	682.5	750	7.5	7.5	315
4	20CR-0.5PE	136.5	613.5	750	11.25	3.75	315
5	20CR-1PE	122.7	627.3	750	7.5	7.5	315
6	30CR-0.5PE	188.19	561.81	750	11.25	3.75	315
7	30CR -1PE	168.54	581.46	750	7.5	7.5	315

2.3 Experimental Method

The mixing process was started by sequentially introducing the cement and fine aggregates and mixed for 3-5 minutes until a uniform consistency was achieved. After that, crumb rubber was gradually added to the mix while maintaining mixing for an additional 2–3 minutes, ensuring proper incorporation. Water was gradually added while mixing, to achieve the desired consistency. Jute fibres and polyester fibres were added into the mixer after the addition of water, while continuing the mix for an additional 2-3 minutes to ensure even fibre dispersion. The mixing was stopped once good consistency was observed. The workability of mix was measured immediately using the slump cone according to ASTM C143, for each test three samples were prepared and performed in this study. After 24 hours of casting, samples were placed into a curing tank full of water for curing. Conduct quality control tests following ASTM standards, including compressive strength ASTM C109 *[32]* and flexural strength ASTM C348*[33].* Cylinders with a diameter of 100 mm and height of 200 mm were prepared to measure rubberized concrete density and water absorption according to ASTM C642 and strength ASTM C109 *[32]*. The water absorption test was conducted by immersing samples in tap water at room temperature. Tap water at room temperature was used to immerse samples to carry out the water absorption test. Samples were weighed before immersion. Weighing of samples took place after 28 days of immersion using a digital scale after drying them by removing surface moisture. The compressive strength at 28 days was determined using concrete cubes of 50 mm as per ASTM C39. According to ASTM C496, the splitting tensile test was performed on cylinders with a height of 200 mm and a diameter of 100 mm. The rubberized concrete elastic modulus was measured through cylindrical samples which were 100mm in diameter and 200mm tall (Figure1b). A strain gauge was attached to the machine side with plates to measure cylinders strain in the loading direction. The elastic modulus was calculated Based on ASTM C469. The universal testing machine's load control setting with a loading rate of 0.5 MPa/s was used. The microstructural analysis involved putting samples under a microscope before analysis was conducted. The concrete prisms with dimensions of 40 mm × 40 mm × 160 mm were prepared to measure flexural strength at 28 days using a vertical comparator according to ASTM C157.

Results and Discussion

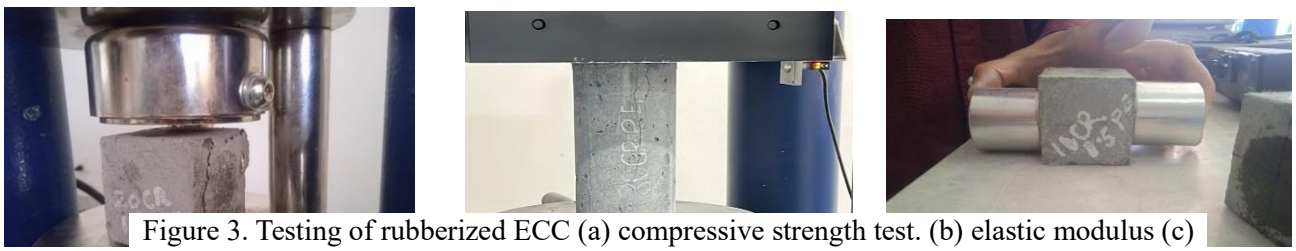


Figure 3. Testing of rubberized ECC (a) compressive strength test. (b) elastic modulus (c) Ultrasonic pulse velocity test.

This section discusses the experimental observations of workability, density, water absorption, and mechanical properties of rubberized ECC with textile fibre.

3.1. Workability

Figure 8 shows the workability results. The control sample exhibited a slump value of 6 mm. It was observed that the introduction of fibres and waste rubber powder significantly reduced the workability of the mixture. Furthermore, as the proportion of polyester fibres increased, the slump values decreased correspondingly. For instance, the slump reduced from 4.5 mm for the 10CR-0.5PE mixture to 2.3 mm for the 10CR-1PE mixture. This decline in workability can be attributed to the higher water absorption capacity of rubber particles that restricts the availability of free water in the mixture, thereby reducing its flowability. Previous studies have reported similar trend, with one study reporting an 11% reduction in workability when 20% of sand was replaced with waste rubber powder, primarily due to rubber's enhanced water absorption properties [34]. Similarly, another study demonstrated a consistent decrease in slump values with increasing percentages of waste rubber powder, further supporting the observed behavior [35].

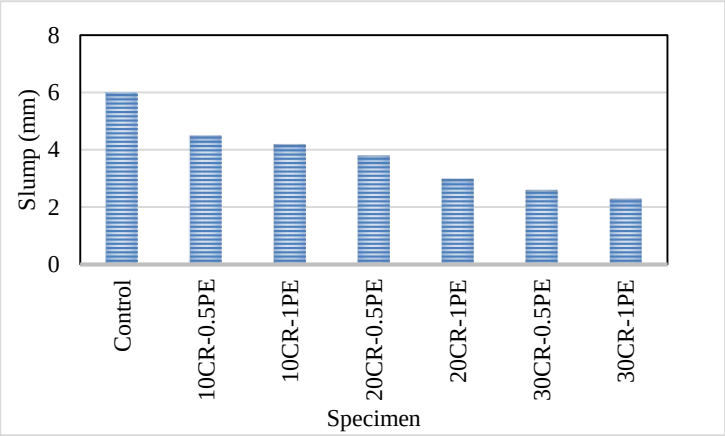


Figure 4. Workability results

3.2. ULTRASONIC IMPULSE VELOCITY

It is observed from Figure 5 that the incorporation of rubber powder resulted in a decrease in pulse velocity. This reduction can be attributed to the presence of fibres and the introduction of voids within the samples due to the addition of rubber. The principle of pulse velocity measurement relies on the uninterrupted transmission of waves through the material; however, the presence of impurities, such as rubber particles and voids, disrupts this transmission, leading to a decline in velocity and, consequently, a reduction in the material's quality. For instance, the direct test for the 10CR-0.5PE mixture yielded a pulse velocity of 3.503 km/s, which, according to the established quality classification, falls within the "good" range for ECC. Conversely, the semi-direct method recorded a higher velocity of 5.556 km/s, indicating an "excellent" quality of ECC.

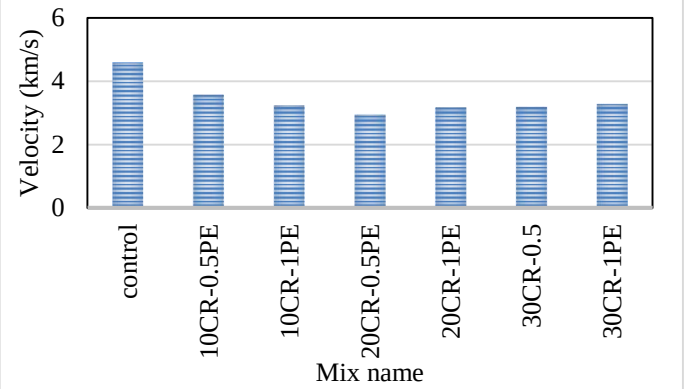


Figure 5. Ultrasonic Impulse Velocity comparison graph.

3.3. Density

Figure 6 presents the density results. The optimal mix batch exhibited a density of 125 lb/ft³ (2011 kg/m³), classifying it within the lightweight range. According to the American Concrete Institute (ACI) standards, lightweight concrete typically falls within the density range of 90 to 115 lb/ft³ (1442 to 1842 kg/m³). The reduced density of the Engineered Cementitious Composite (ECC) after incorporating waste rubber powder can be attributed to the lower specific gravity of rubber compared to fine aggregates. Specifically, the specific gravity of rubber is 1.05, whereas that of fine aggregate is 2.66. This significant difference in specific gravity results in a lighter overall density for rubberized ECC [36, 37]. Furthermore, multiple studies have reported a linear reduction in density with the incorporation of waste rubber powder as a partial replacement for sand, corroborating the observed trend [38-40]. This reduction in density not only aligns with the properties of lightweight concrete but also highlights the potential of rubberized ECC as a sustainable and lightweight construction material.

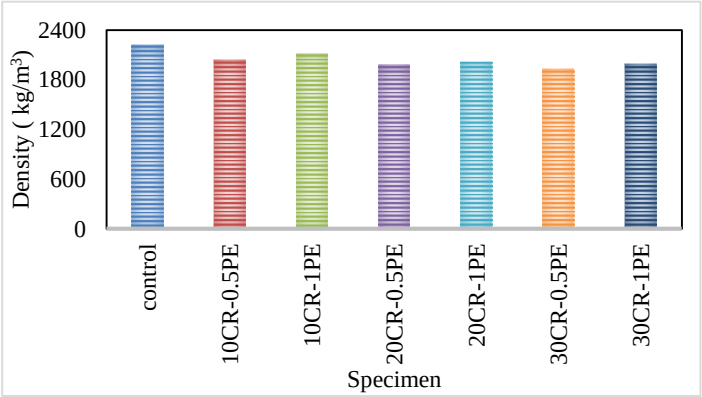
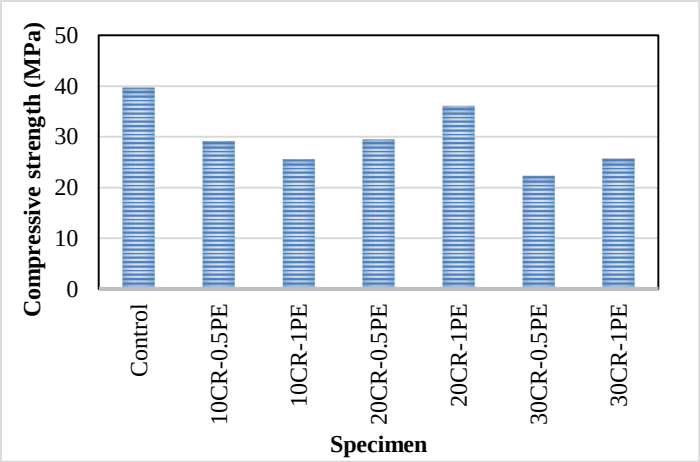


Figure 6. Density of ECC

3.4. Compressive strength

It is observed from Figure 7 that after reaching the ultimate strength, the fibre reinforced specimens exhibit a regain in strength due to the fiber bridging effect. This phenomenon occurs as the fibers bridge microcracks, redistributing stress and enhancing post-cracking behavior. In contrast, tests conducted on specimens containing only rubber (without fibres) demonstrated a decline in strength as the rubber content increased. This reduction in strength is attributed to the lower stiffness and bonding properties of rubber compared to traditional aggregates. However, the incorporation of fibres mitigated this strength

loss, compensating for the weakening effect of rubber. Among the tested mixtures, the optimum strength was observed in the 20CR-1PE specimen that contained 20% rubber and 1% polyester fibers. This combination achieved a balance between rubber content and fibre reinforcement, highlighting the critical



role of fibres in enhancing the mechanical performance of rubberized ECC. These findings underscore the importance of fibre reinforcement in maintaining structural integrity and improving the overall strength of rubber-modified ECC.

Figure 7. Compressive strength test results

3.5. Splitting tensile strength

Figure 8 exhibits the spilling tensile strength results. The results demonstrated that the splitting tensile strength was significantly decreased as the rubber was incorporated into the ECC. While the incorporation of fibres mitigated this strength loss, compensating for the weakening effect caused by the rubber. Among the tested mixtures, the optimum strength was achieved in the 20CR-1PE specimen that contained 20% rubber and 1% polyester fibers. This combination struck a balance between rubber content and fiber reinforcement, highlighting the critical role of fibers in enhancing the mechanical performance of rubberized ECC.

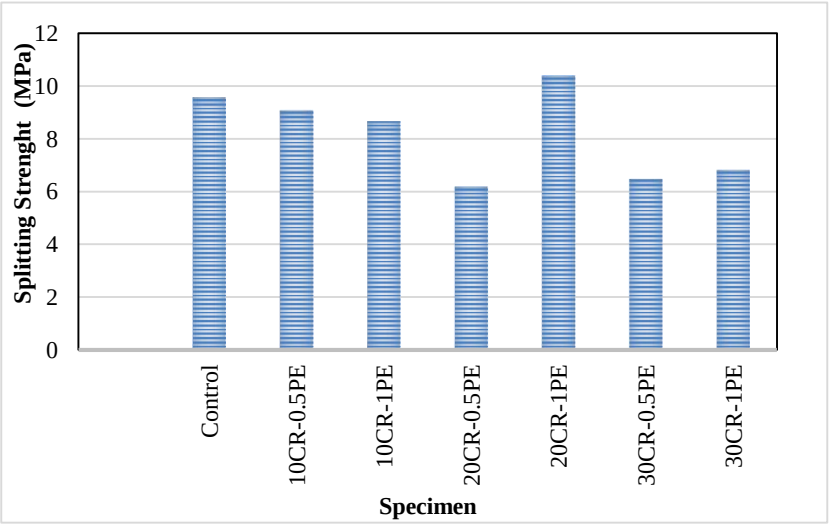
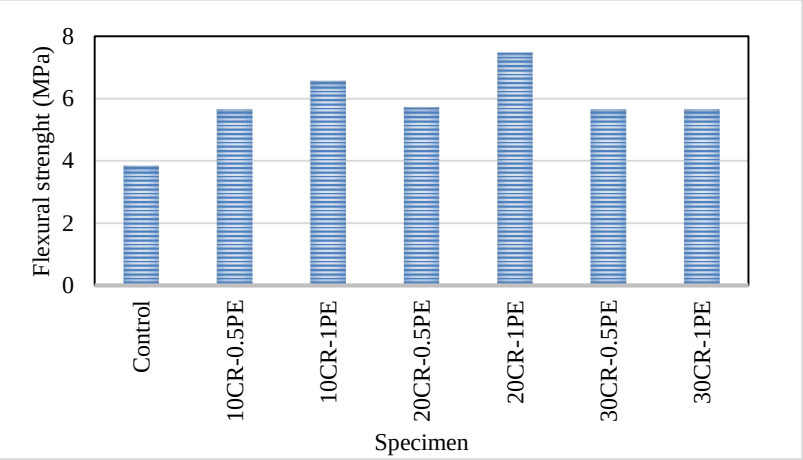


Figure 8. Splitting tensile strength results

3.6. *Flexural strength*

The results of flexural strength tests for the control sample and ECC incorporating waste rubber powder at varying percentages (10% to 30%) are presented in Figure 9. The control sample exhibited the lowest flexural strength, while the fibre reinforced ECC samples, particularly those with a 1:1 fibre ratio, demonstrated the highest strength. This enhancement in strength can be attributed to the fibre bridging effect, where fibres act as reinforcements to redistribute stress and inhibit crack propagation. Additionally, the ductile properties of the fibres contribute to their ability to arrest cracks effectively. It was further observed that fibres aligned in the transverse direction performed exceptionally well in resisting tensile stresses, thereby significantly improving crack resistance. This behaviour is due to the ability of fibres to absorb and dissipate energy, preventing the initiation and spread of cracks.

Figure 9. Flexural strength results



3.7. *Elastic modulus*

The elastic modulus results are presented in the Table 2. It was observed that the elastic modulus of rubberized ECC with hybrid fibres is lower than that of conventional concrete. The elastic modulus that represents the stiffness of a material, is influenced by the composition of the ECC. In contrast to conventional concrete, ECC does not contain coarse aggregates, which are typically responsible for providing higher stiffness. The absence of coarse aggregates, combined with the incorporation of rubber and hybrid fibers, results in a reduction in the overall stiffness of the material, thereby lowering its elastic modulus. This reduction is further attributed to the flexible nature of rubber and the ductile behavior of hybrid fibers. While enhancing toughness and crack resistance, contribute to a decrease in rigidity. These findings align with the expected behavior of ECC that prioritizes ductility and strain capacity over stiffness, making it suitable for applications requiring flexibility and energy absorption.

Table 2. Elastic modulus

Mix Name	Elastic modulus (GPa)
Control	29.62
10CR 0.5PE	25.36
10CR-1PE	23.75
20CR-0.5PE	25.51
20CR-1PE	28.24

30CR-0.5PE	22.19
30CR-1PE	23.81

3. Conclusion

This study investigated the effects of various percentages of rubber and hybrid fibres on the workability, ultrasonic pulse velocity and mechanical properties of ECC. Based on the experimental findings, the following conclusions have been drawn:

- The optimal mix design containing 20% waste rubber powder, 1% jute fibre, and 1% polyester fibre, which demonstrated superior mechanical properties, including a compressive strength of 36 MPa, tensile strength of 10.402 MPa, and flexural strength of 7.48 MPa, outperforming conventional concrete.
- The incorporation of waste rubber powder and hybrid fibres (jute and polyester) significantly enhanced the tensile and flexural strengths of ECC, with flexural strength reaching 10-15% of the compressive strength, highlighting the improved ductility and crack resistance of ECC.
- Excessive amounts of waste rubber powder and fibres led to a decline in mechanical performance, emphasizing the need for careful optimization of mix proportions to balance sustainability and structural integrity.

This study comprehensively analysed the mechanical properties of ECC containing rubber and hybrid fibres. Future studies should evaluate the long-term durability of rubberized ECC, including its resistance to environmental factors such as weathering, chemical attack, and fatigue loading

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MONITORING LAND COVER CHANGES IN CHOTIARI RESERVOIR AND ITS 5.0 KM^2 BUFFER USING GIS (1990–2023)

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ABSTRACT: In response to climate change, Chotiari Reservoir, a crucial wetland ecosystem in Pakistan, has experienced prominent landscape modifications and environmental transformations over the last three decades. This study leverages Geographic Information System (GIS) and remote sensing techniques to investigate temporal variations in water bodies, vegetation, and barren land within the reservoir and its 5.0 Km2 buffer zone from 1990 to 2023. Imagery from the Landsat satellite was acquired from USGS Earth Explorer and processed using ArcGIS 10.8 and Google Earth to identify landscape modifications and environmental transformations. The unsupervised classification method was employed in ArcGIS using ArcTools composition to group and evaluate landscape modifications throughout the period. The outcomes demonstrate significant changes in the ecological and hydrological landscape, influenced by climatic variations, water management practices, and artificial activities. This study delivers analytical interpretations of the prolonged landscape transformations of Chotiari Reservoir, emphasizing the need for sustainable and integrated conservation strategies for water resource management, ensuring its availability for a long period, and efficient utilization by designing innovative planning and implementation of policy. The GIS-based technique employed in this research is a robust framework for monitoring wetland ecosystems and supporting data-driven policy decisions.

KEYWORDS: remote sensing, unsupervised classification technique, temporal change detection

1. Introduction

Normally, the lands secured by water are marked as wetlands. As indicated by the National Wetland Policy of Nepal (2003), those water bodies that are lasting and made by underground wellsprings of water sources or potentially rainfalls are named wetlands. It implies wetlands are swampy zones with stagnant or flowing fresh or brackish water. They may be boggy zones, waterway flood fields, lakes, marshes, ponds, or regions of water storage. They might be natural or man-made. Natural wetlands incorporate waterways, streams, lakes, marshes, lowlands, and artificial wetlands to incorporate as trenches, lakes, paddy fields, fish ranches, and so on. They are filled up with water seasonally, and the water might be stale or moving in the wetlands. They cover around six percent of the surface zone of the Earth and are

found in nearly every nation directly from the tundra district to the tropical zones [1].

Pakistan has a wide range of wetlands all over the country, according to the Ramsar Convention, which provides a guideline for national action and international cooperation for the protection and management of wetland ecosystems and their resources. Pakistan has included 19 wetland sites, which have been recognized as 'Ramsar Sites' and bear global importance. Chotiari is one of Pakistan's most diversified wetland sites, which was changed into a reservoir from a lake in 2002. The project of Chotiari reservoir is planned for the increment of storage capacity of existing natural lakes in the Chotiari wetland area, which is expanded over 180 km2. Primarily, it was intended to store Indus flood water during the flood seasons from June to September, and to release the water to bring down the Nara Canal during the winter season from December to March, just as in early summer from April to June. Its fundamental objective was to irrigate about 0.12 million hectares in the nation [2].
Tools like GIS and remote sensing enable great tracking of hydrological dynamics, land use change, and loss of vegetation, especially multi-temporal satellite data like Landsat, which provide important insights into long-term variations in the environment [3].

2. Area of Study

Chotiari is located in Sanghar district, Sindh. Sanghar District is one of the largest districts of Sindh province, Pakistan. It's located in the centre of Sindh and is bounded to the east by India. Chotiari Reservoir is located 35 km northeast of Sanghar Town, District Sanghar, Province Sindh, Pakistan at 26.3 N Latitude, 69.5 E Longitude. It inflated over 180 km2 and 60 meters above the sea level.

3. Data and Software Used

For achieving the objectives of this study, the data was collected from earthexplorer.usgs.gov for the 1990

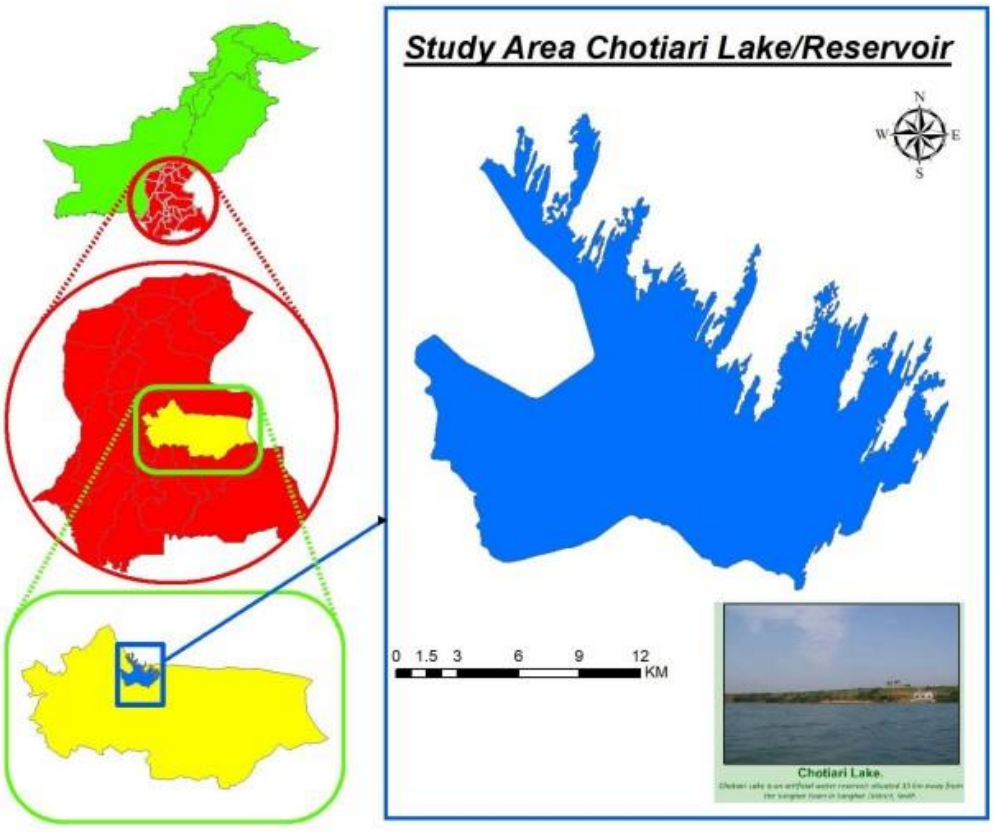

Figure 1. Location of Study Area

image of Landsat 5, and the 2023 image of Landsat 8 is used; both images have a spatial resolution of 30x30 meters. The images of February are used for both years. For image classification of February 1990, Bands 1,2,3,4,5, and 7 of Landsat 5 are used, and for February 2023, Bands from 1 to 7 of Landsat 8 are used. ArcGIS 10.3.1 and Google Earth software are used for finding the temporal variations in Chotiari Lake and its buffer of 5 km.

4. Methodology

Landsat images are acquired from eathexplorer.usgs.gov and then in ArcGIS by using Arc Tools composition of the different bands of satellite images is carried out before further analysis of satellite image the area of interest is extracted from the entire satellite image by using masking technique after that for finding areas of vegetation, water and barren land the technique of Unsupervised Classification of satellite imagery is used.

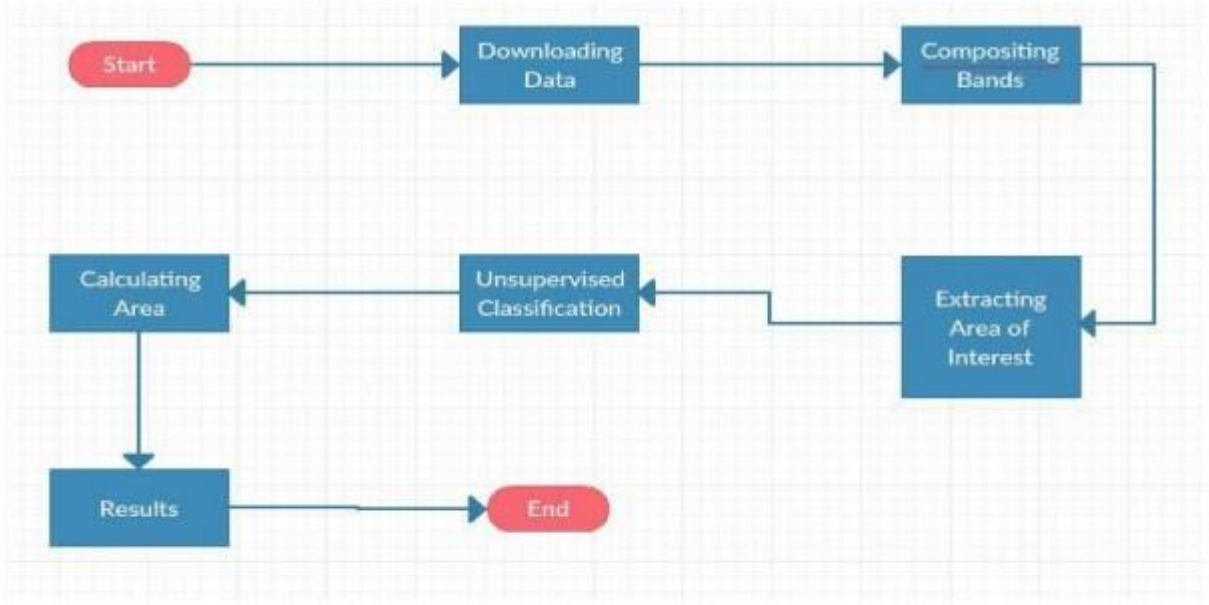

Figure 2. Flow chart of Methodology

5. Image Classification by using ArcGIS

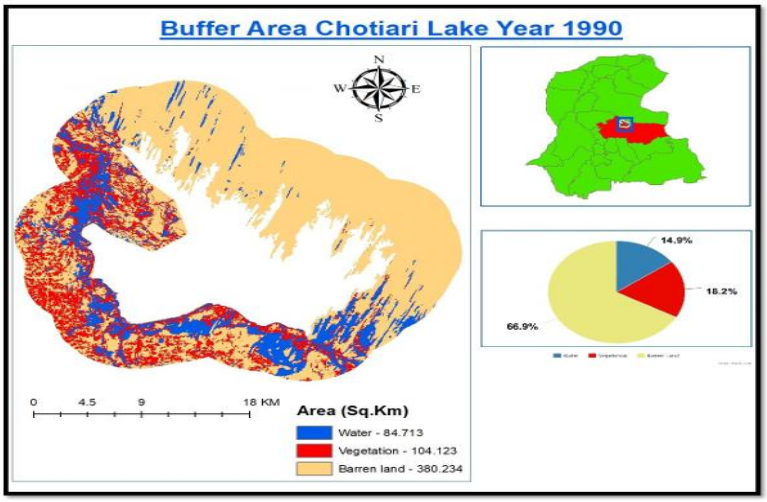

Figure 5. Image classification of Chotiari Lake Buffer area of year 1990

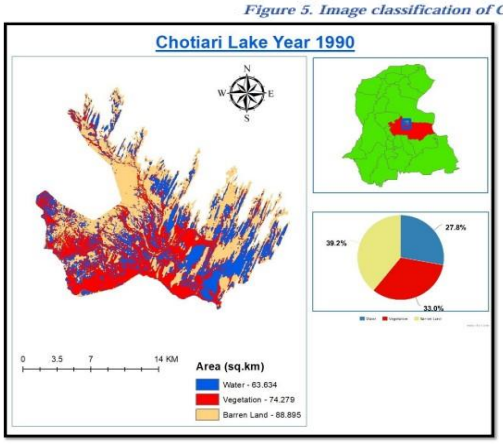

Figure 3. Image classification of Chotiari Lake area of year 1990

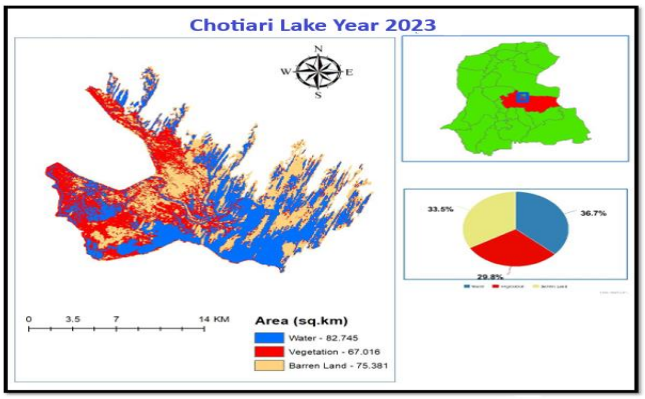

Figure 4: Image classification of Chotiari Lake 2023

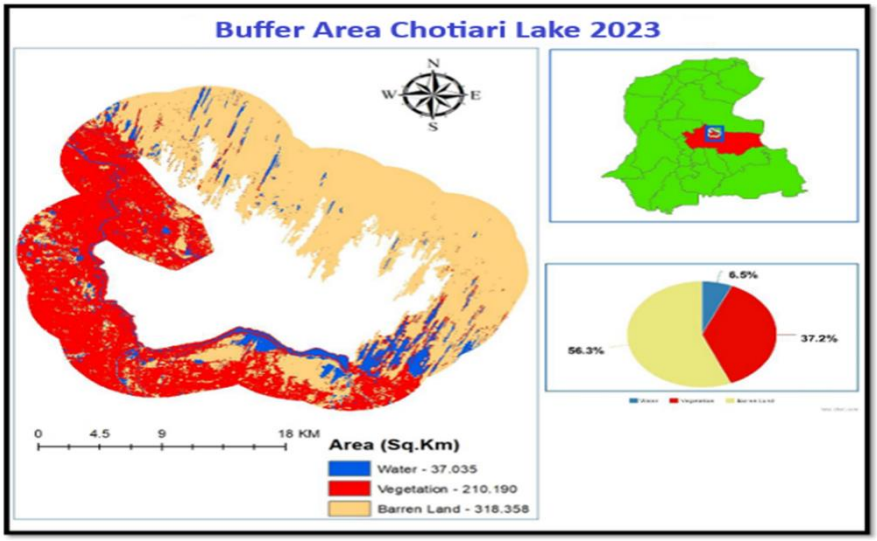

Figure 6: Image classification of Chotiari Lake buffer area 2023

6. Results and Discussion

According to our objectives of the study, the area of chotiari lake which is 225 km^2 and area of its 5km buffer zone which is 565 km2 are divided into three classes Water, Vegetation and Barren land and the results of temporal variations of 2 years which are February, 1990 and February, 2023 are shown in figure 7 and figure 8.

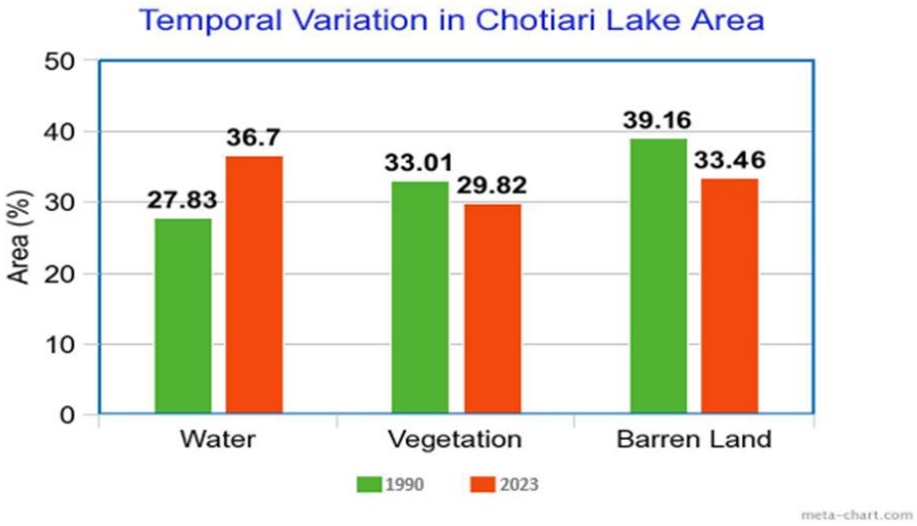

Figure 7. Temporal Variations in Chotiari Lake area

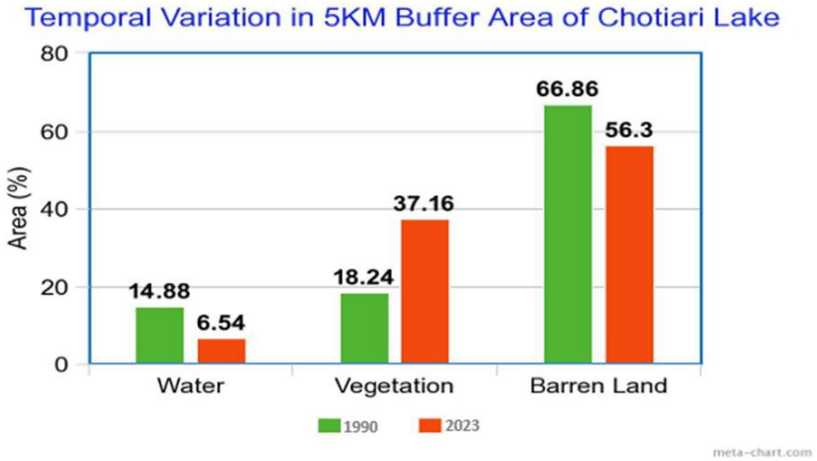

Figure 8. Temporal Variations in Chotiari Lake Buffer area

7. Conclusion

It is concluded that after comparison of data of both the years, after construction of reservoir in Chotiari lake water is increased by 9%, vegetation and barren land is reducing to 4% and 5% respectively and in 5KM buffer area of Chotiari lake vegetation is increased by 19% and water and barren land reduces to 8% and 10% respectively.

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Subject: Water Resource and Environmental Engineering

Theme: Environmental Impact Assessment and Sustainable Planning

Ref: 1st ICSIID//KHP/20

Optimization of Waste Biomass Blends via Torrefaction and Densification for Industrial Use

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ABSTRACT: Power plants are significant contributors to greenhouse gas emissions, which drive global warming and climate change. Over the past two to three decades, efforts have increasingly focused on reducing reliance on coal and transitioning to cleaner energy sources. This shift has sparked interest in torrefaction, a process that enhances the energy content of biomass—a renewable and environmentally friendly energy source—to levels comparable to or even surpassing coal. One key advantage of torrefied biomass is its ability to be co-fired with coal, effectively reducing emissions, lowering greenhouse gases, and mitigating global warming. It is important to consider various parameters like temperature, oxygen content, heating rate and residence time which can control torrefaction and achieve the best biomass with properties comparable to those of coal. The research investigates the torrefaction and densification of waste biomass to optimize its industrial application for emission reduction. The study explores the effectiveness of dry and wet torrefaction processes on various waste biomass types including localized waste biomass and wood cellulose pulp residue. This research is aimed to address handling and transportation challenges and further improve energy content; economic analysis will indicate that both processes are commercially viable with minimal selling prices. Extensive research will be done to explore the potential of combining torrefaction with densification to produce high quality pallets which will burn efficiently and reduce emissions in industrial applications. The research will focus on the importance of optimizing processing condition and explore future technologies for sustainable energy solutions.

Keywords: Torrefaction, Densification, Pallets, Greenhouse effect, Global warming

Introduction

To minimize the release of harmful gases, torrefied biomass can be used to partially substitute coal in energy production [1]. The gases released during the combustion of torrefied biomass are part of the natural carbon cycle, as biomass is derived from carbon dioxide absorbed from the atmosphere through photosynthesis [2]. Recently, there has been significant interest in using torrefied biomass in existing large-scale combined heat and power (CHP) plants for co-firing with coal, without requiring any modifications to the plant design [3]. The process and biomass potential usage in Pakistan can be understand by following picture [4]

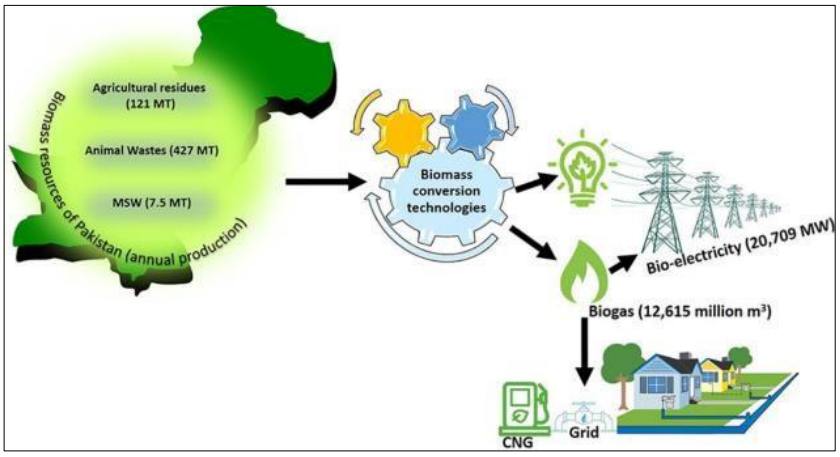

Figure 1: Bioenergy Production in Pakistan [4]

The direct use of biomass as fuel is hindered by its low utilization efficiency. To address this drawback, studies have demonstrated that thermal and physical treatment processes can significantly enhance the energy density of biomass [5]. Research efforts primarily focus on understanding the compositional changes in solid biomass and analyzing product distribution [6]. A key challenge for biomass as an energy source is its low bulk density, which typically ranges from 80–100 kg/m³ for agricultural straws and grasses, and 150–200 kg/m³ for woody materials like wood chips [7, 8].

The low bulk density of biomass poses significant challenges for storage, transportation, and utilization. It also creates complications for technologies like coal co-firing, as differences in bulk density can hinder fuel feeding into boilers and reduce combustion efficiency. Densification offers a promising solution to these issues. Through mechanical compression, densification increases biomass density by approximately tenfold. Commercially, this process is carried out using pellet mills, extrusion systems, briquetting presses, or roller presses, effectively addressing challenges related to feeding, storage, handling, and transportation.

Figure 2: Process & Types of Densification [9]

The urgent global imperative to address climate change and reduce carbon emissions has catalyzed a concerted effort to explore and implement alternative energy sources. Among the diverse range of alternatives, biomass stands out due to its inherent renewable properties and potential for achieving

carbon neutrality. As a biological material derived from organic matter, biomass has long been considered a promising candidate for sustainable energy production. However, the direct utilization of raw biomass in industrial applications is fraught with challenges that hinder its efficiency and feasibility. These challenges include its low energy density, high moisture content, and logistical inefficiencies, all of which complicate its use as a reliable and effective energy source.

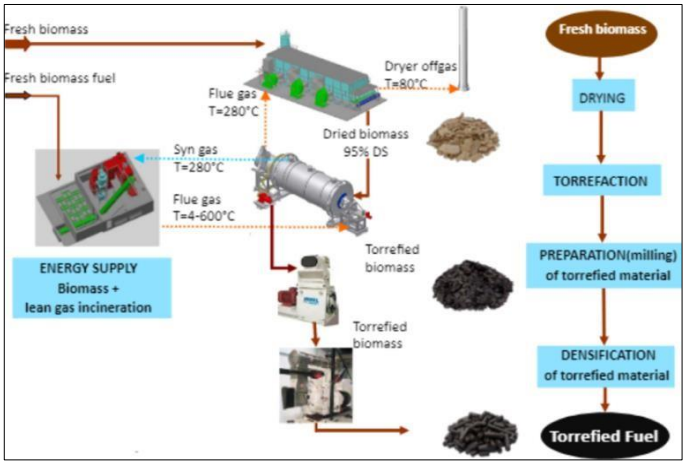

Figure 3: Process of Torrefaction [10]

To overcome these limitations, advanced processing techniques such as torrefaction and densification have been developed. Torrefaction is a thermal pretreatment process performed at temperatures ranging from 200°C to 300°C in an inert or low-oxygen environment. During this process, the biomass undergoes partial decomposition, particularly of hemicellulose, which leads to a reduction in moisture content and an enhancement in energy density. The torrefied biomass acquires several advantageous properties: it becomes more hydrophobic, thereby improving its resistance to biological degradation and making it easier to store and handle. Additionally, torrefaction improves the grind ability of the biomass, making it suitable for blending with coal in existing power plants. This characteristic enables the potential reduction of the carbon footprint associated with conventional coal combustion. Torrefaction is done through pyrolysis technique, as shown below:

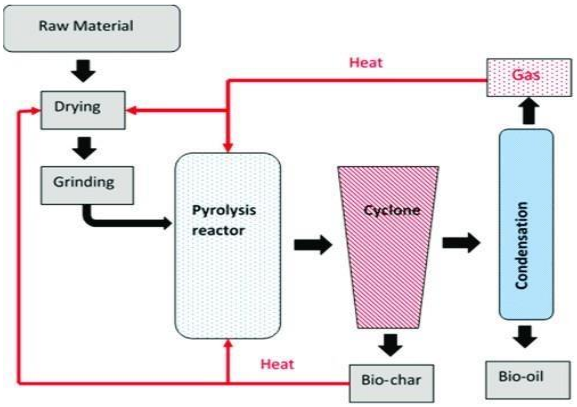

Figure 4: General layout of pyrolysis process [11]

Methodology

Studies for the characterisation of biomass in terms of their physical and chemical properties and

thermochemical characteristics are essential in developing a suitable pre-treatment facility as well as in the designing and construction of a suitable thermal conversion system, which is simple, reliable, efficient and economical [12]. Biomass wastes vary greatly in their physical, chemical and thermal characteristics, however, these characteristics are usually less complex compared to those of the municipal solid waste, which consists of a variety of individual type of waste. This makes agricultural wastes relatively simpler to process with less cost for feed preparation procedure.

It is important to know about the characteristics of biomass wastes and identify their suitability for the gasification/combustion. This primary characterization includes the proximate, elemental and thermo gravimetric analyses [13]. The agricultural residues include wheat waste, rice husks [14] , cotton waste and bagasse biomass waste. The physical characteristics of solid waste such as particle size and shape distribution, and bulk density are important parameters to be considered in the designing of a thermal conversion system. Bulk density also plays an important role in the design of feeder system to the reactor. Bulk density depends upon the moisture content, shape and the size of particle of the solid waste. This property varies depending upon the waste preparation method employed. It is well established that there is a close relationship between feed particle size and products from thermal processing arising from kinetic consideration and rates of heat transfer However, for thermo gravimetric analysis, smaller particle sizes are recommended as to avoid internal heat transfer restriction.

Biomass Sample Collection and Preparation

Samples of wheat straw, rice husk [16], bagasse, and cotton waste were collected from agricultural farms. Each sample was air-dried, ground, and sieved to a uniform particle size (≤500 μm) for analysis.

Proximate Analysis

Proximate analysis was conducted following ASTM standards, determining Moisture content (105°C, 24 hours), Volatile matter (950°C, 7 minutes), fixed carbon (by difference and Ash content (750°C, 6 hours) [15]

Ultimate Analysis

Ultimate analysis was performed using an elemental analyzer (CHNS-O), determining carbon (C), hydrogen (H), nitrogen (N), sulfur (S), and oxygen (O) content. Oxygen was estimated by difference. [17]

Thermo Gravimetric Analysis (TGA)

TGA was performed using a PerkinElmer Pyris 1 TGA instrument under a nitrogen atmosphere (20 mL/min) at a heating rate of 10°C/min from room temperature to 800°C. [18]

Results and Discussion

Proximate Analysis

Table 1: Proximate Analysis of Biomass Samples (%)

Biomass	Moisture	Volatile Matter	Fixed Carbon	Ash
Wheat Straw	7.8	70.2	15.6	6.4
Rice Husk	9.2	64.5	12.8	13.5
Bagasse	8.5	75.3	13.1	3.1
Cotton Straw	6.7	76.8	14.5	2

Bagasse and cotton straw exhibited higher volatile matter, indicating better combustion properties. Rice husk had the highest ash content, affecting its energy efficiency. [15]

Ultimate Analysis

Table 2: Ultimate Analysis of Biomass Samples (% by weight)

Biomass	C	H	N	S	O (by diff.)
Wheat Straw	45.1	6.2	0.7	0.2	47.8
Rice Husk	42.3	5.8	0.9	0.3	50.7
Bagasse	47.6	6.4	0.5	0.1	45.4
Cotton Straw	48.8	6.9	0.3	0.1	43.9

Cotton straw and bagasse has higher carbon content, making them more suitable for biofuel applications. Rice husk contained higher oxygen, leading to lower energy yield. [17]

Thermo-gravimetric Analysis (TGA): The TGA curves of rice husk, cotton straw, sugar cane bagasse and wheat straw respectively are shown as under:-

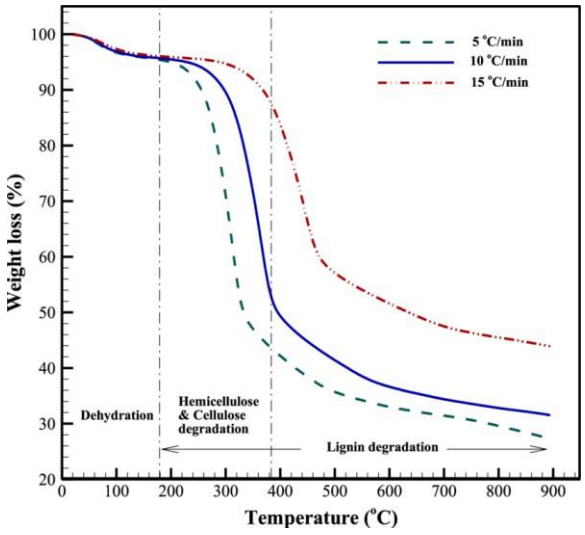

Figure 5: TGA Curve of rice husk [20]

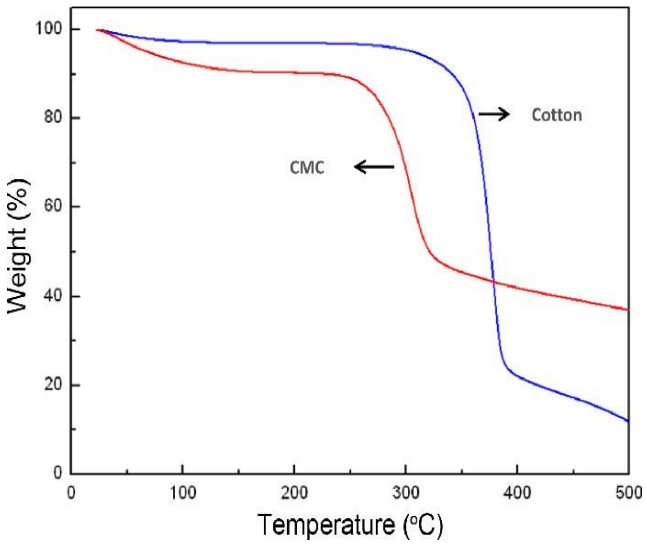

Figure 6: TGA Curve of cotton straw [21]

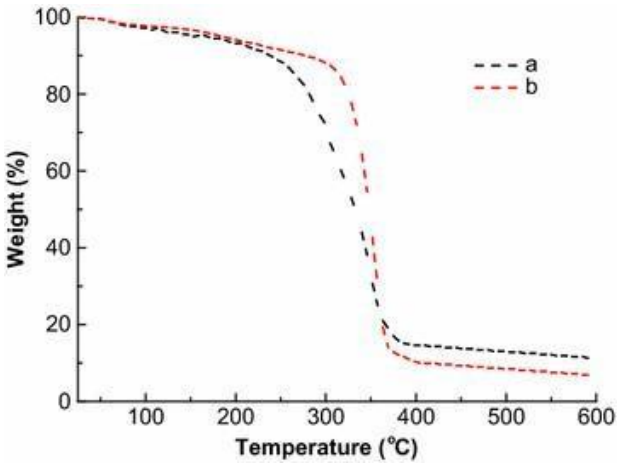

Figure 7: TGA Curve of bagasse [22]

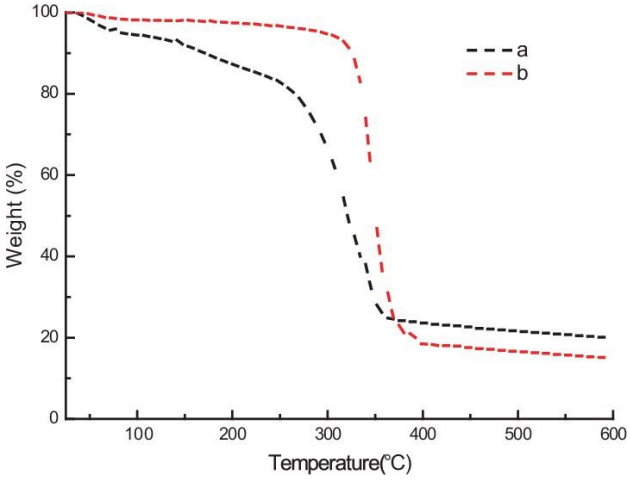

Figure 8: TGA Curve of wheat straw [23]

Thermal decomposition occurred in three stages first moisture evaporation (50-150°C) in which minimal weight loss due to moisture release second is active pyrolysis (200-500°C) in which major weight loss occurs from volatile matter decomposition and the third is Char Decomposition (500-800°C) in which fixed carbon breakdown. Bagasse exhibited the highest degradation rate, while rice husk showed residual mass due to high ash content. Wheat straw has a high volatile content (~70%), making it highly reactive in pyrolysis and combustion processes. [18] [19]

4. Conclusion

The study demonstrated significant differences in the thermal and chemical properties of wheat straw, rice husk, bagasse, and cotton straw. Bagasse and cotton straw exhibited superior combustion properties, whereas rice husk showed limitations due to high ash content. Wheat straw exhibits good thermal behavior however it has high ash content which can be reduced by chemical processing. The findings provide valuable insights into biomass selection for energy applications.

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Subject: Structural and Geotechnical Engineering

Theme: Advanced Construction Materials and Technologies

Ref: 1st ICSIID//KHP/25

DEVELOPMENT OF FIBER-REINFORCED SELF-COMPACTING CONCRETE MODIFIED WITH RICE HUSK ASH AND FLY ASH

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Abstract
Self-Compacting Concrete (SCC) is a notable innovation in construction, capable of flowing into confined structural spaces without vibration. While SCC is celebrated for its superior workability and predictable strength, further enhancements can be achieved by incorporating polypropylene fibers (PPF) and supplementary cementitious materials (SCMs). However, the influence of Rice Husk Ash (RHA) on SCC, particularly in ternary blends with SCMs like fly ash, remains underexplored. This research investigates the mechanical performance of SCC mixes with a fixed 20% fly ash, varying RHA contents (5%, 10%, 15%, and 20%), and PPF proportions (0.1%, 0.25%, 0.5%, and 0.75%). The experimental program involved preparing a reference mix without RHA or PPF and conducting compressive and tensile strength tests for all combinations. The inclusion of RHA and PPF aimed to improve the crack resistance, toughness, and overall mechanical properties of SCC. Results indicate that the optimum performance is achieved at 10% RHA and 0.5% PPF, where significant improvements in compressive and tensile strength were observed. The study highlights the synergistic effect of RHA and PPF in enhancing SCC properties, particularly crack resistance and toughness, while maintaining its self-compacting ability. These findings contribute to sustainable and high-performance concrete technologies, offering valuable insights into modern construction practices aimed at achieving improved durability and sustainability.
Keywords: Self-Compacting Concrete, Rice Husk Ash, Polypropylene Fibers, Ternary Concrete Blends

4. Introduction

The introduction of Self-Compacting Concrete (SCC) has significantly advanced concrete technology by offering superior flowability and compaction without the need for mechanical vibration. This property makes SCC particularly suitable for applications with dense reinforcement, where traditional vibration techniques are inefficient [1,2]. Consequently, SCC adoption is increasing worldwide, particularly for high-reinforcement structures, and it is expected to gradually replace conventional vibrated concrete, especially in high-rise construction projects. However, the growing demand for concrete in large-scale, high-rise buildings may make standard-strength SCC less ideal for meeting the required performance standards [3–5].
Despite its advantages, SCC requires a higher volume of cement than conventional concrete [1], which raises sustainability concerns, as cement production is a major source of CO_2 emissions [6].

To mitigate these environmental impacts, incorporating supplementary cementitious materials (SCMs) as partial replacements for cement has become essential. However, the addition of SCMs can influence the fresh properties, hydration kinetics, and hardened characteristics of the concrete [7,8].

Among the promising SCMs, Rice Husk Ash (RHA), a pozzolanic material, has shown potential for improving concrete's hardened properties and durability, like silica fume, when appropriately treated [9]. Rice husk, constituting about one-fifth of the total weight of dry rice, generates substantial quantities of waste globally, with an estimated 148 million tons of rice husk produced annually [10]. In countries like Pakistan, rice husk accounts for 22% of the total rice crop weight, much of which is discarded in landfills [11]. By incorporating RHA into concrete, the environmental impact of this waste can be reduced, while also decreasing the demand for cement, lowering concrete production costs, and reducing CO_2 emissions from cement manufacturing. However, RHA affects the fresh properties of concrete, particularly workability. Research by Chopra and Siddique [12] found that mixes with 20% RHA as a cement replacement exhibited the lowest workability. In contrast, mixes with 5% and 10% RHA, combined with superplasticizer dosages of 3.5–4.5%, fell within the EFNARC [13] recommended slump flow range (650–800 mm), while the V-funnel test values were generally below 6 seconds [14], indicating increased viscosity with higher RHA content.
Similarly, the incorporation of Fly Ash (FA) into concrete is well-documented for enhancing workability and contributing to the long-term strength development of the material. FA reduces the need for superplasticizers, achieving comparable slump flow to mixes using only cement as the binder [15]. Furthermore, studies have demonstrated that SCC containing high FA volumes exhibits strength and shrinkage properties like conventional concrete, with variations dependent on water-to-binder ratios [16]. Based on existing literature, the optimal fly ash content in concrete typically ranges from 10% to 30%, depending on specific mix designs and performance requirements [17].
Furthermore, concrete, including SCC, often exhibits low flexural and tensile strength, as well as limited resistance to cracking and shrinkage [18]. The addition of fibers, particularly Polypropylene Fibers (PPF), can significantly enhance the mechanical properties of SCC [19]. Fiber incorporation provides several benefits, such as increased fracture energy, reduced crack width, decreased shrinkage, and improved flexural and tensile strength and overall durability. While some studies suggest that fibers have minimal effect on the modulus of elasticity or compressive strength, the impact is often contingent on the type and dosage of fibers used [20]. Fiber characteristics, such as mass, length-to-diameter ratio (L/D), and shape, can also influence concrete properties. High surface area fibers with small diameters can reduce SCC workability [19,21]. Some research suggests that fiber volume fractions above 0.5% may adversely affect SCC's fresh properties [21]. However, incorporating macro-PP fibers (up to 0.45%) has been shown to significantly improve the mechanical properties of Fiber-Reinforced Concrete (FRC), including flexural strength, fracture resistance, tensile strength, ductility, resilience, and overall serviceability [22–24].
This paper aims to explore the combined effects of Rice Husk Ash (RHA), Polypropylene Fibers (PPF), and Fly Ash (FA) on the mechanical properties and workability of Self-Compacting Concrete (SCC). The study examines varying RHA contents (5%, 10%, 15%, and 20%), PPF dosages (0.1%, 0.25%, 0.5%, and 0.75%), and a fixed 20% FA content, with the goal of identifying the optimal combination of these materials to enhance strength, durability, crack resistance, and self-compacting ability. By exploring the synergies between RHA, PPF, and FA, this research aims to contribute to the development of more sustainable, high-performance concrete materials for modern construction

5. Experimental Procedure

5.1 Materials

The Portland cement used in this study complies with ISO 9001:2000 standards and meets the specifications outlined in ASTM C150 [17]. The physical and chemical properties of the Portland cement are summarized in Table 3. For the coarse aggregates, a maximum size of 19 mm was selected, in accordance with ASTM C33M to prevent blockages during the casting of Self-Compacting Concrete (SCC). The fine aggregates, with a particle size less than 4.75 mm, meet the requirements of ASTM C33 [18]. The physical properties of both coarse and fine aggregates are provided in Table 1.

Table 1: Physical properties of fine and coarse aggregate

Properties	Fine Aggregates	Coarse Aggregates
Specific Gravity	2.60	2.58
Fineness Modulus	2.50	6.22
Surface Texture	Smooth	Rough
Particle Shape	Rounded	Angular

The superplasticizer (BASF brand) was used as an admixture to improve workability. A constant dosage of 0.8% by binder weight was found to provide optimal workability, reducing the excess water required to achieve the desired flowability of the SCC. Additionally, Fly Ash and Rice Husk Ash (RHA) were incorporated in the mix. The Fly Ash content was kept constant at 20% of the cement weight, while the RHA content varied from 5%, 10%, 15%, and 20%. The Polypropylene Fiber (PPF) content varied from 0.1% to 0.75% by weight of the cement. The chemical properties of OPC, Fly Ash and RHA are provided in Table 2.

Table 2: Chemical properties of OPC, fly ash and RHA

Chemical Properties	OPC %	Fly Ash %	RHA %
SiO_2	20.75	52.5	78.7
Al_2O_3	5.50	25.0	0.28
Fe_2O3_3	4.31	7.2	0.11
CaO	61.50	2.5	1.50
MgO	1.95	1.8	0.22
Na_2O	0.30	0.6	0.08
K_2O	0.65	2.5	2.30

5.2 Mix Proportions

The SCC mix designs were developed based on standard SCC guidelines, with Fly Ash fixed at 20% of

cement weight and RHA varying between 5%, 10%, 15%, and 20% by weight of cement. The PPF content was varied from 0.1% to 0.75% of the cement weight. A total of 17 mix designs were prepared, as listed in Table 3.

Table 3: Mix Design

Mix ID	Cement (kg/m³)	Fly Ash (kg/m³)	RHA (kg/m³)	Fine Aggregate (kg/m³)	Coarse Aggregate (kg/m³)	Water (kg/m³)	Superplasticizer (kg/m³)	PPF Fiber (%)	PPF Fiber (kg/m³)
Ref	400	80	0	264	397.2	180	3.84	0	0
M1	379.6	80	20	264	397.2	180	3.84	0.1	0.4
M2	379	80	20	264	397.2	180	3.84	0.25	1.0
M3	378	80	20	264	397.2	180	3.84	0.5	2.0
M4	377	80	20	264	397.2	180	3.84	0.75	3.0
M5	359.6	80	40	264	397.2	180	3.84	0.1	0.4
M6	359	80	40	264	397.2	180	3.84	0.25	1.0
M7	358	80	40	264	397.2	180	3.84	0.5	2.0
M8	357	80	40	264	397.2	180	3.84	0.75	3.0
M9	339.6	80	60	264	397.2	180	3.84	0.1	0.4
M10	339	80	60	264	397.2	180	3.84	0.25	1.0
M11	338	80	60	264	397.2	180	3.84	0.5	2.0
M12	337	80	60	264	397.2	180	3.84	0.75	3.0
M13	319.6	80	80	264	397.2	180	3.84	0.1	0.4
M14	319	80	80	264	397.2	180	3.84	0.25	1.0
M15	318	80	80	264	397.2	180	3.84	0.5	2.0
M16	317	80	80	264	397.2	180	3.84	0.75	3.0

5.3 Preparation of Specimens and Testing

Self-compatibility of the concrete mix was ensured by following standard testing procedures. Concrete was poured into moulds without any mechanical vibration. For compressive strength (ASTM C39) testing, cubic specimens (100x100x100 mm) were cast and cured in tap water. Splitting Tensile Strength Test was conducted in accordance with ASTM C496 using 150 mm × 300 mm concrete cylinders. After 28 days of curing, the compressive and tensile strength were measured.

5.4 Concrete Tests

5.4.1 Fresh Concrete

To evaluate the fresh properties of the concrete, the slump test was performed. The test assesses the filling ability and passing ability of the SCC.

5.4.2 Hardened Concrete

For hardened concrete, compressive and tensile tests were conducted on specimens after curing in tap water. The strengths were measured using a Universal Testing Machine (UTM) with a capacity of 200 kN, applying a loading rate of 0.3 MPa/s.

5.5 Research Methodology

The development of SCC followed a trial-and-error approach. The fresh properties of the concrete were determined after finalizing the mix proportions. Fig. 1 illustrates the experimental setup for

evaluating fresh properties.
To evaluate the hardened properties of SCC, a total of 50 cubic and cylinder specimens were tested for each age group (14 and 28 days). The specimens were prepared and cured at 23 ± 2°C using the admixtures of Fly Ash and RHA as mentioned earlier. After curing, the compressive and tensile strength of the specimens were measured, and the results were recorded at 28 days as presented in section 3.

Figure 1: Casting/curing of cubes and cylinders

6. Results and Discussion

6.1 Fresh Concrete Properties

The slump flow results for all SCC mixes are presented in Fig. 2. As the RHA content and PPF content increased, a slight decrease in slump flow was observed. This was expected, as both RHA and PPF contributed to the increase in viscosity, which reduced the ease of flow. However, all mixes, including those with higher RHA and PPF contents, remained within the EFNARC range for SCC, which requires a slump flow between 650–800 mm. Therefore, although the maximum slump flow was not achieved at the optimum mix, the workability was still within acceptable limits for self-compacting concrete.

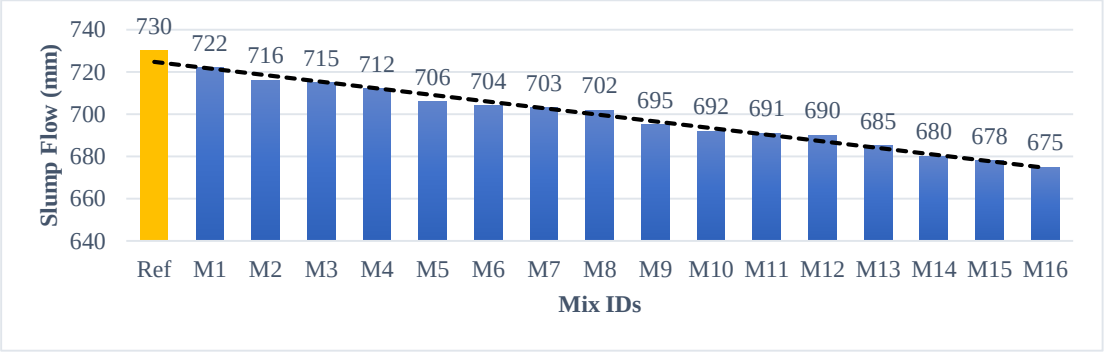

Figure 2: Slump flow of Fiber reinforced SCC

6.2 Mechanical Properties

6.2.1 Compressive Strength

The compressive strength of the SCC mixes was evaluated at 28 days of curing. The results are illustrated in Fig. 3. The reference mix (without RHA and PPF) showed a compressive strength of 32 MPa at 28 days. The optimum mix with 10% RHA and 0.5% PPF demonstrated the highest compressive strength of 42 MPa at 28 days. Other mixes with varying RHA contents (5%, 15%, and 20%) showed a decrease in compressive strength compared to the optimum mix. However, the mix with 10% RHA and 0.5% PPF outperformed all other combinations, indicating the significant positive impact of this specific mix design on the overall strength.

The increase in compressive strength at the optimum mix can be attributed to the combined effect of RHA and PPF, which improve both the matrix strength and crack resistance. RHA enhances the pozzolanic reaction, contributing to improved long-term strength, while PPF fibers provide internal reinforcement that helps prevent micro-cracking and improves overall toughness.

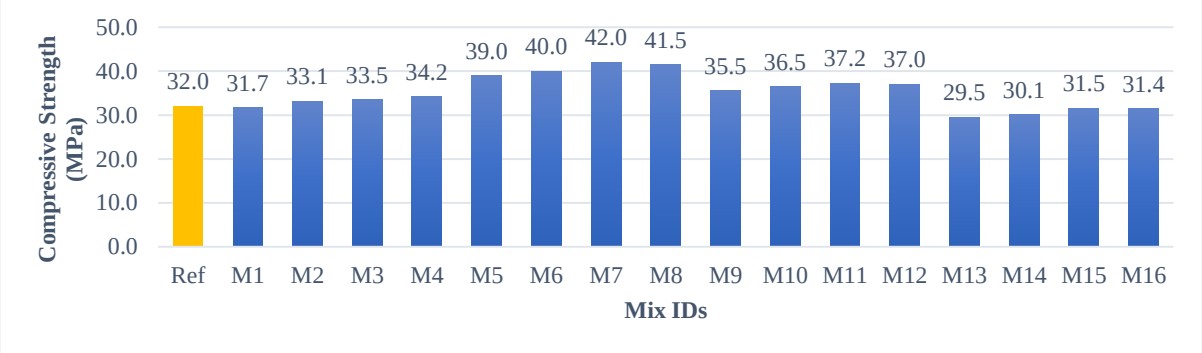

Figure 3: Compressive Strength (MPa) of fiber reinforced concrete at 28 days

6.2.2 Tensile Strength

The splitting tensile strength was tested for all mixes at 28 days curing. The results are summarized in Fig 4. For the reference mix, the tensile strength was 6.5 MPa at 28 days. The optimum mix (10% RHA and 0.5% PPF) exhibited a tensile strength of 7.5 MPa at 28 days, significantly outperforming the reference mix and other RHA/PPF combinations.
The increased tensile strength of the optimum mix can be attributed to the reinforcing effect of the PPF, which help to distribute stresses more evenly within the concrete matrix, preventing crack propagation and improving durability. The RHA further contributes by enhancing the bond between the cement matrix and aggregates, improving the overall tensile resistance.

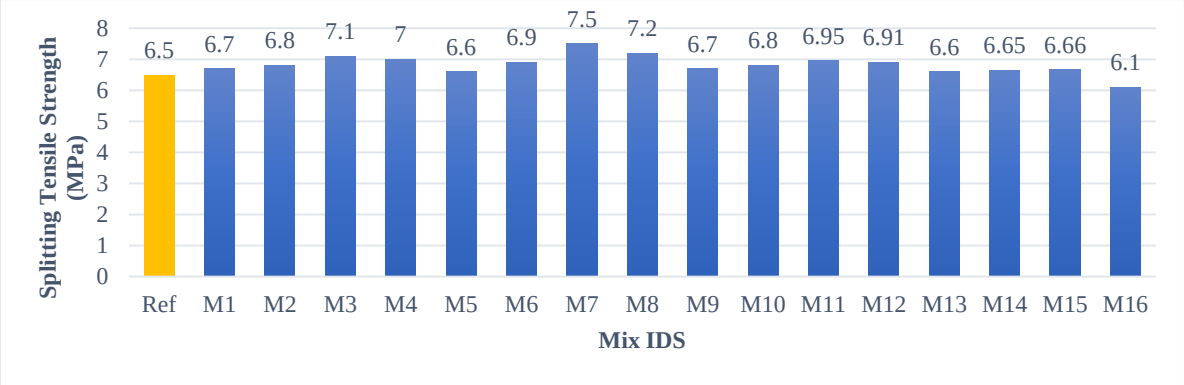

Figure 4: Tensile Strength (MPa) of fiber reinforced concrete at 28 days

Conclusion

This study demonstrated the effectiveness of incorporating Rice Husk Ash and Polypropylene Fiber into Self-Compacting Concrete for enhancing its mechanical properties.

- The optimum mix was achieved with 10% RHA and 0.5% PPF, resulting in a compressive strength of 42 MPa and tensile strength of 7.5 MPa at 28 days, showing significant improvements over the reference mix.
- The synergistic effects of RHA and PPF not only enhanced compressive and tensile strength, but also maintained workability within the EFNARC range, making it suitable for high-performance, sustainable concrete applications.

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Strength and durability of Recycled Aggregate Concrete with different SCMs

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ABSTRACT: Human population growth causes the development of millions of tons of solid waste globally where demolished concrete stands as one of the most widespread construction residues. The rise in urbanization together with expansion of infrastructure poses a major environmental issue regarding construction and demolition waste disposal. The investigation of sustainable waste management solutions has increased notably within the last few years because researchers focus on replacing virgin coarse aggregates with recycled concrete aggregates for concrete production. The usage of recycled aggregate (RA) in concrete production replaces natural aggregate (NA) in a sustainable manner though recycled aggregate concrete (RAC) usually displays decreased mechanical properties and reduced durability attributes. Research incorporates supplementary cementitious materials SF and MK to improve this weak performance. Control mix performance escalated by 5.8% when developed with 50% RA and 10% MK and 5% SF to showcase a compressive strength of 4112.7 psi at 28 days. Acid resistance decreases when increasing RCA content since the 75% RCA mix showed 20% higher deterioration than the control sample. Experimental results show that combined SF and MK inclusion improves mechanical robustness and durability of concrete structures when using recycled materials to satisfy contemporary building requirements.

KEYWORDS: NC: Natural Concrete; NAC: Natural Aggregate Concrete; RAC: Recycled Aggregate Concrete; SCMs: Secondary Cementtious Metials; MK: Metakoalin; SF: Silica Fume

1. Introduction

Humans are producing millions of tons of solids waste around the globe and one of the mostly produced wastes is demolished concrete. In the past few years, a lot of research has been conducted to use this waste concrete as coarse aggregate to use as the replacement of virgin aggregates to produce ecofriendly concrete. As revealed by United Nations reporting (2017) national populations worldwide will surpass 9.77 billion during 2050 while demonstrating a 30% increase from 2017 numbers. Demographic expansion drives increased construction work that leads to faster production of construction and demolition waste.

Waste production happens during highway excavation activities and maintenance stages as well as new building development and maintenance work and demolition operations (Wong et al., 2018). C&D waste forms 28% of landfill solid waste in Hong Kong according to the Environmental Protection Department (2017). Research revealed C&D waste exceeded 1.53 million tons in 2015

and this number indicated a 6.6% rise above the previous year's totals. [1]. To manage this C&D waste and to relief natural resources it is necessary to utilize this waste in an efficient manner. Further, it is necessary to check the performance of such concrete under immense temperature that whether it could withstand such forces to prevent the occupants from harm as there is a probability that structure will expose to fire for once in a life span.

2. Materials and Methodology

2.1 Effects of Materials on RAC

The main binder material of concrete is cement because it initiates the hydration process to create calcium silicate hydrate (C-S-H) gel that supports strength development. RAC contains residual mortar that generates weak areas as it affects the concrete structure by lowering strength and enhancing material permeability [2]. The concrete matrix achieves improved density and durability when combined with SCMs consisting of silica fume and metakaolin because these additives enhance ITZ strength and activate pozzolanic reactions while improving packing efficiency [3]. Silica fume functions as a highly reactive material stemming from silicon and ferrosilicon alloy production because it possesses an extensive surface area along with amorphous silica composition. The addition of silica fume to RAC leads to an increased production of C-S-H gel through its chemical reaction with calcium hydroxide from cement hydration thus delivering improved strength and durability characteristics and lower porosity [4]. Silica fume particles settle into concrete voids which improves ITZ refinement and produces major permeability reduction [5]. Silica fume changes RAC into a material which demonstrates improved resistance to damaging sulfate exposures together with chloride intrusion and carbon dioxide intrusion [6]. Fresh RAC becomes more workable with better cohesion capabilities because of silica fume addition [7]. Metakaolin demonstrates significant importance as a high reactive pozzolanic substance derived from kaolinite clay calcination to enhance RAC's mechanical characteristics and durability [8]. Through its chemical reaction with CH metakaolin creates more C-S-H and aluminates that strengthen this material both mechanically and increase its durability according to [9] [10]. This material provides effective shrinkage and creep reduction which tackles a fundamental issue related to RAC structures [11]. Metakaolin acts as a supplement to enhance RAC's sulfate resistance as well as limit alkali-silica reaction (ASR) and minimize efflorescence formation to deliver superior long-term performance [12]. RAC material benefits from silica fume and metakaolin integration because both additives mutually enhance microstructure refinement and cement paste densification as well as ITZ strengthening[13]. Physical and chemical properties of cementitious materials are given below:

Table 1: Physical and Chemical Characteristics of OPC, Metakaolin and Silica Fume

Property	Metakaolin	Ordinary Portland Cement	Silica fume
Physical Characteristics			
Finess (m^2/kg)	12581	328	15671
Specific Gravity	2.64	3.29	2.39
Color	White	Dark Grey	Light to Dark Grey
Chemical Characteristics			
Magnesium oxide (MgO)	0.4	4.56	0.2-0.8
Potassium oxide (K_2O)	-	0.51	0.5-1.2

Calcium oxide (CaO)	0.5	61.61	0.2-0.8
Aluminum oxide (Al_2O_3)	43	5.04	1.12
Iron oxide (Fe_2O_3)	1.2	3.16	1.46
Silicon dioxide (SiO_2)	53	20.25	85
Sodium oxide (Na_2O)	-	0.08	0.5-1.2
Sulphur Oxide (SO_3)	-	2.94	-
Loss on ignition	0.4	3.12	<6.0

The combined effect between silica fume and metakaolin generates superior mechanical properties which produce greater compressive and tensile strength while providing more resistance to environmental attack [14]. The durability properties improvement in RAC creates an ecologically sound concrete solution that incorporates recycled materials effectively [15]. Performance evaluation of concrete depends on measuring both compressive strength and durability effects from natural and recycled aggregate usage. Concrete strength and durability increase due to natural aggregates from quarries because these materials provide regular quality alongside enhanced mechanical features. Concrete mix design and performance can be affected by using recycled aggregates because these materials absorb more water and have corresponding effects on density and create more porous structures.

Table:2 Physical Properties of Sand, Natural and Recycled aggregates

Property Name	Sand	Natural Aggregates	Recycled Aggregates
Abrasion Resistance (%)	-	18.72	33.62
Fineness Modulus	2.63	3.59	4.19
Bulk Density ($kg/m^{3)}$	1571	1710	1385
Water Absorption (%)	3.97	3.47	4.56
Specific Gravity	2.77	2.51	2.59

2.2 Research Methodology

This research investigates the compressive resistance as well as acid resistance of concrete made with recycled aggregate incorporating silica fume and metakaolin as partial replacement of cement acting as SCMs. The methodology involves a systematic experimental approach. Recycled concrete aggregates (RCA) are sourced from demolished concrete, cleaned, and sieved to meet standard grading requirements. Metakaolin was incorporated in a decreasing interval of 2.5% from 12.5% to 7.5% whereas silica fume was incorporated in increasing of 2.5% from 2.5-7.5% to assess their impact on RAC performance as a partial substitute of cement and NA was replaced at 25% increment with RA up to 75%. A control mix with natural aggregates and OPC is also prepared for comparison. The concrete mixes are designed following ACI mix design guidelines, maintaining a constant W/B ratio to ensure consistency across all batches. After mixing, specimens are cast into standard cylindrical molds (4” dia and 12” height) and cured. Compressive strength tests were conducted at 14, 28 and 90 days to evaluate the strength development of each mix. To assess acid resistance, cured specimens are immersed in a 5% sulfuric acid ($H_2 SO_4$) solution for 14 days.

Then surface deterioration and residual compressive strength after acid exposure are recorded to determine the durability performance of RAC with silica fume and metakaolin. The findings are then compared with existing literature to validate the effectiveness of silica fume and metakaolin in enhancing RAC's mechanical and durability properties.

3. Result and Discussion:

3.1 Compressive Strength:

The influence of RA together with MK and SF on concrete compressive strength can be observed through Figure 1 during different curing periods. The combinations of both Metakaolin and Silica Fume produced concrete mixtures showing the highest strength performance is matched by the 10% MK and 5% SF mixture. The specimens containing no additive showed weaker strength results compared to other samples.

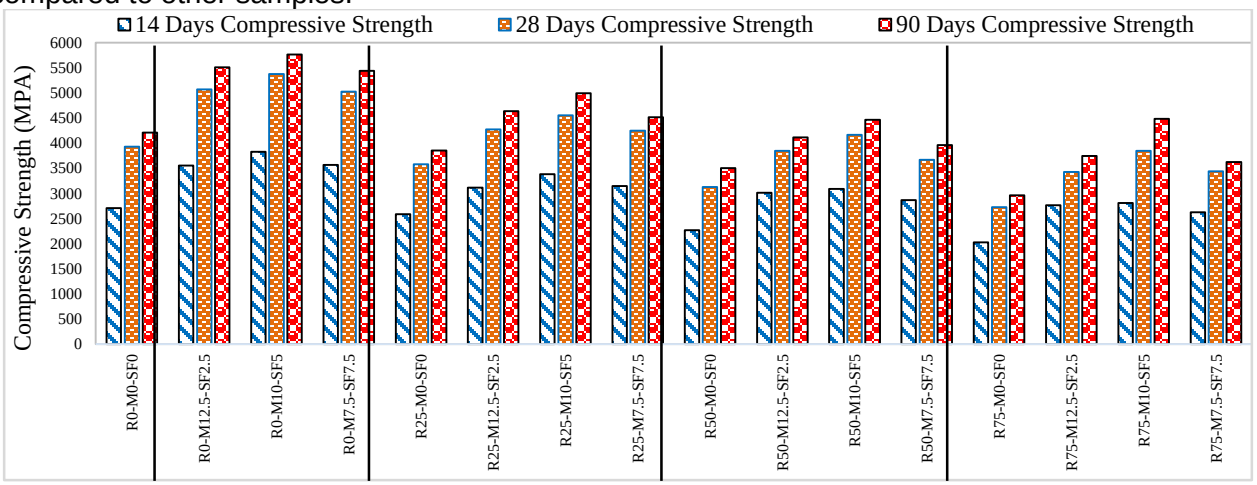

Fig 1: Compressive of RAC with MK-SF at Different Curing Age

Tests showed that when using a 50% RA replacement strategy the concrete material achieved 5.8% increased strength at 28 days and 12.8% increased strength at 90 days relative to the control group at 28 days. The concrete microstructure undergoes improvements due to MK and SF activity that enhances hydration speed and density formation which together strengthen bearing capacity. The use of RA compromised the structural integrity of concrete; however, increasing the proportion of MK and SF not only mitigated this effect but also led to a slight strength enhancement compared to the control mix. The improved performance can be attributed to the increased surface area of MK and SF, which enhances matrix density, reduces porosity, and lowers permeability, ultimately improving compressive strength [14]. As the proportion of natural aggregate is replaced with RA, a decline in compressive strength is observed. At a 75% replacement level, strength is reduced by 30.9% compared to the control mix (R0-MK0-SF0) after 28 days of curing. Similarly, a 50% replacement results in a 20.6% strength reduction for (MK0-SF0). Nevertheless, the inclusion of MK and SF allows for the replacement of up to 50% of natural aggregate with RA while still achieving strength improvements after 90 days, as demonstrated by the strength values of 4186.2 psi for RA-0 with no MK and SF, and 4447.2 psi for RA-50 with 10% MK and 5% SF.

3.2 Acid Resistant Test:

The acid resistance measurements of RAC started with the analysis of 14-day strength before submerging all specimens in a 5% sulfuric acid solution for 90 days. The compressive strength tests were executed after the exposure period to determine material durability. The combination of MK at 10% and SF at 5% yielded concrete that showed maximum acid resistance. Sulfuric acid produces significant damage to cement-based materials through its reaction with calcium hydroxide (CH) that turns the material into gypsum ($CaSO_4 \cdot 2H_2O$) while causing expansion and surface deterioration. The sulfate ions join with tricalcium aluminate (C_3A) in cement to create expansive ettringite that damages the structure through internal strain development.

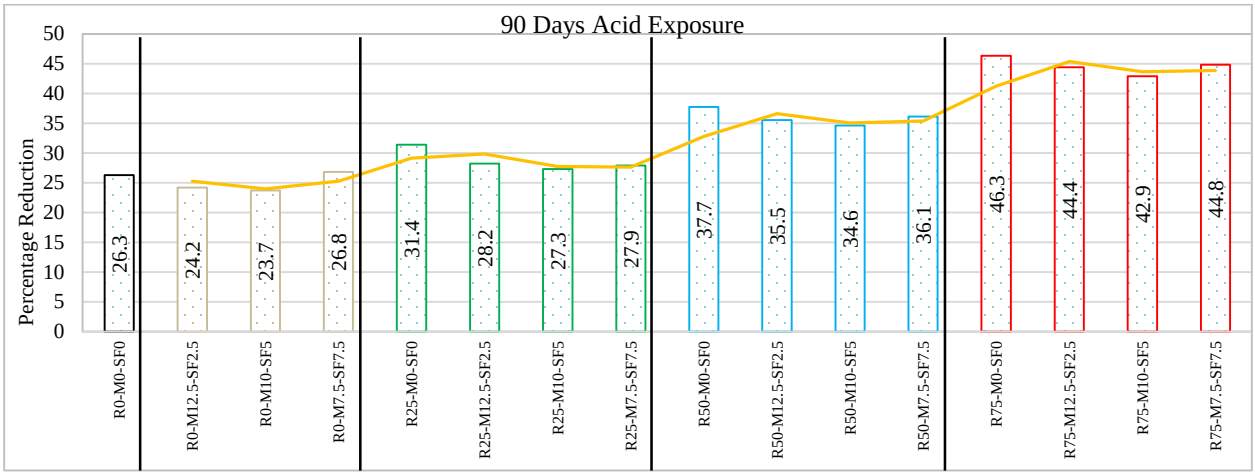

Fig 2: Strength reduction in percentage at 90 days Acid Exposure

The main binding component of cement known as C-S-H gel demonstrates deterioration when exposed to acidic settings that leads to a gradual material strength reduction over time [16]. Incorporating MK and SF significantly enhances the acid resistance of concrete compared to conventional RAC by reducing mass loss and improving long-term durability. However, while these additives improve resistance to acid-induced deterioration, they do not provide complete immunity against damage. Experimental results indicate that as the recycled coarse aggregate (RCA) content increases from 0% to 75%, the acid resistance of RAC declines, with strength reductions ranging from 26.3% to 46.3%. Figure 2 illustrates the percentage reduction in strength across different mixtures. The M10-SF5 mix exhibited a 23.7% strength loss at 0% RCA, which progressively increased to 27.3% at 25% RCA, 34.6% at 50% RCA, and reached its highest reduction of 42.9% at 75% RCA.

4. Conclusions

Higher amounts of recycled aggregates substituted for natural aggregates result in simultaneous strength reduction and acid sensitivity deterioration. Metakaolin and silica fume integration produces concrete matrix refinement along with densification effects that result from SCM hydration consumption. Structures can maintain their integrity when using 10% MK and 5% SF as replacement

additives that enable RA to substitute 50% natural aggregates without strength reduction. More compressive strength of 5.8% emerged at 28 days when using concrete that contained the MK and SF mixture along with 100% natural aggregate over the control mix without these additives. The addition of RCA content at 75% produces the maximum acid resistance deterioration. Strong performance improvements from metakaolin and silica fume in concrete must be balanced against diminishing strength at 50% and above RCA replacement levels toward structural applications. When using 10% metakaolin with 5% silica fume we obtain an efficient cement replacement and performance improvement in concrete containing up to 50% recycled aggregates. The mixed blend enhances both mechanical properties and reduces water absorption for better durability performance. The additive provides excellent fire resistance capabilities to recycle aggregate concrete while acting as a highly advantageous modification option.

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Subject: Structural and Geotechnical Engineering

Theme: Advanced Construction Materials and Technologies

Ref: 1st ICSIID//KHP/27

INVESTIGATING THE EFFECT OF RAW BENTONITE, SILICA FUME AND POLYPROPYLENE FIBERS ON THE WORKABILITY AND COMPRESSIVE STRENGTH OF CONCRETE

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ABSTRACT: The construction industry is always looking for the materials that improve the performance of concrete for durable and efficient structures. This research evaluates the effect of raw bentonite, silica fume (SF), and polypropylene fibers on the workability and compressive strength of concrete. Bentonite is a very high siliceous (SiO_2) pozzolanic clay material that can act as a supplementary cementitious material (SCM) to enhance the strength and sustainability. Production of silica fume, which is an important pozzolanic material, occurs during the manufacturing processes of ferrosilicon and silicon alloys, that exhibits pozzolanic activity as well as increased strength and reduced permeability. PPF enhances tensile strength and resistance to cracking. 10 concrete mixtures were made in total, where bentonite (5% and 15%) and silica fume (5%) substituted cement by weight, while PPF (0.75%, 1.00%, and 1.25%) was added by concrete volume. A control mix (CC) without bentonite, silica fume, or PPF was also used. Slump test was performed to assess workability, whereas compressive strength test was performed to determine the mechanical property. The results reveal that workability is reduced in all mixes as a result of using SCMs and PPF. The mechanical strength is enhanced with the optimum overall strength exhibited by the combination of 5% bentonite, 5% silica fume, and 1% PPF. Mechanical strength of concrete is improved by utilizing these materials, which makes them ideal for structural applications.

KEYWORDS: Bentonite, compressive strength, polypropylene fibers, silica fume, workability

7. Introduction

Concrete is the most utilized building material worldwide. However ongoing growth of infrastructure globally has tremendously boosted cement consumption since cement is the main binder in concrete. As the demand for construction materials goes up, so does the amount of cement produced, which creates environmental grave concerns. Cement production is one of the largest emitters of carbon dioxide worldwide and share about 8% in human-induced carbon dioxide emissions [1]. Cement manufacturing through calcination serves as the main source of industrial

emissions because this procedure requires extensive energy usage that produces carbon dioxide emissions. Moreover, the exhaustion of natural materials necessary to produce cement, including limestone and clay, has created issues with regards to the sustainability of traditional concrete [2]. Thus, mentioned environmental and other resource problems are being positively tackled in the construction sector and more sustainable alternatives are being pursued to minimize cement reliance while keeping intact or even improving concrete performance [3]. Cement could be partially replaced with supplementary cementitious materials. SCMs are naturally occurring pozzolanic substances or industrial by-products that, upon addition to concrete, enhance mechanical properties, lower carbon emissions, and provide overall durability improvement [4]. The materials undergo pozzolanic reaction when combined with calcium hydroxide (CH) and water while forming C-S-H gel that serves as principal strength component of concrete [5]. Research on alternative cementitious approaches and fiber reinforcement system has been achieved as the most promoted search area in sustainable construction and have advantageous properties in terms of strength and durability [6].

Among the SCMs, silica fume (SF) and bentonite have also demonstrated high promise in concrete property modification. Bentonite is fine-grained alumino-silicate clay with good plasticity and pozzolanic characteristics, making it an apt partial cement replacement. The composition of silica (SiO_2) and alumina (Al_2 O_3) in bentonite material enables cement hydration that produces refined pore structures and long-term strength increases [7]. Also, bentonite's capacity to improve cohesion and stability in fresh concrete renders it useful for minimizing segregation and bleeding in concrete mixtures [8]. When cement is partially substituted with bentonite material outcomes include enhanced concrete strength characteristics and improved structural integrity. [9].

Silica fume emerges as a production byproduct from silicon and ferrosilicon alloy processing because it demonstrates both pozzolanic characteristics and exceptional capabilities to fill concrete voids. Because it has an ultrafine particle size and high surface area, silica fume succeeds in minimizing porosity, augmenting density, and improving bonding of cementitous materials [10]. It is especially efficient in enhancing concrete strength and lowering permeability, and hence it is one of the most common high-performance SCMs applied in contemporary concrete technology. Structural concrete performance and mechanical strength receive improvements when silica fume is added to concrete mixtures through densification of its microstructure [11]. Besides SCMs, fiber reinforcement is also a proven method for concrete toughness and crack resistance. The ductility and energy absorption capability of concrete increases when fibers are added to the mix [12]. Of the synthetic fibers, polypropylene fibers are extensively utilized because they exhibit high tensile strength. The application of PPF increases concrete tensile strength together with toughness and impact resistance and effectively controls plastic shrinkage cracks in fresh concrete [13]. Incidental to their use in concrete structures enhances the ability to manage dynamic loads which makes them suitable for high-performance applications. PPF addition, however, influences fresh concrete workability since fiber dispersion in the mix may cause higher internal friction and lower flowability [14]. This requires changes in proportions of mix design to realize the best compromise between workability and strength.

Studies on synergistic influence of bentonite and silica fume with PP fibers in structural concrete need to be investigated. Knowledge about SCM and fiber reinforcement effects on fresh and hardened properties will help develop optimal concrete mix designs. The strength properties depend on the relationship between SCMs and fiber reinforcement which requires additional research for proper real-world mix proportion determination.

The investigation in this research focuses on the interaction of bentonite, silica SF, and PPF in structural concrete to analyze their impact on workability as well strength characteristics. The workability of concrete materials gets measured using slump cone methods and mechanical performance is evaluated by analyzing compressive strength test. This investigation on the combined behavior of SCMs coupled with fibers helps develop eco-friendly concrete mixture designs which are necessary for the development of sustainable concrete materials.

8. Materials and Methodology

2.1 Materials Description

Concrete workability as well as mechanical properties rely on materials physical and chemical specifications. This research utilized bentonite, silica fume (SF) and polypropylene fibers (PPF) to create concrete mixture. The concrete mixtures contained ordinary portland cement (Type I) as their main binder followed by ASTM C150 [15]. Bentonite utilized here came from its natural resources of Jahangira (Nowshera) Pakistan. It was replaced by weight of cement (5% and 15%). Silica fume, a pozzolanic material was replaced at constant 5% by weight of cement. It served to refine microstructure while improving the properties. The properties of OPC, BN and SF are mentioned in Table 1.

Table 1: Properties of OPC, Bentonite and SF

Chemicals	SiO^2	TiO^2	Al_2O^3	Fe_2O^3	MnO	MgO	CaO	Na_2 O	K_2O	LOI
OPC		17.4	-	10.1	3.61	-	1.82	62.2	0.91	1.42
Bentonite	56.87	1.46	15.44	12.26	-	3.7	0.54	-	-	6.8
Silica fume	92	-	-	-	-	-	-	-	-	2.6

Coarse aggregate (CA) used in concrete was obtained from Margalla Hills Source. Its maximum size was 20mm. Its absorption capacity is 0.55% and specific gravity is 2.7. Fineness modulus (FM) of natural river sand was 2.99. Portable water was used in all concrete mixtures. The characteristics of fine aggregate (FA) and coarse aggregate (CA) are shown in Table 2. Length of PP fibers used in mix is 15 mm. Table 3 shows the reported properties of PPF according to its manufacturer [16].

Table 2: Properties of Inert Materials

	FA	CA
Specific gravity	2.65	2.7
Water absorption (%age)	1.2	0.55
Loose density (Kg/m3)	-	1416
Rodded density (Kg/m3)	-	1560
F.M	2.99	-

Table 3: Properties of Polypropylene Fibers

Tensile Strength at Breakage (MPa)	31-41 [17]
Elongation at Breakage (%)	100-600 [17]
Youngs Modulus (MPa)	1137-1551 [17]
Specific Gravity	0.9-0.91 [18]

A total of 10 mix proportions were used to evaluate workability and compressive strength of concrete. Ordinary Portland Cement (OPC) was substituted with bentonite at 5% and 15%. All mixes involved silica fume held constant at 5% replacement by weight of cement. Polypropylene fibers (PPF) were also added at dosage levels of 0.75%, 1% and 1.25%, by volume of concrete. A w/c ratio of 0.5 was utilized for the mixture preparation. A series of mixtures were prepared for experimental purpose to determine workability and strength-related effects produced by bentonite, silica fume and PPF. The mix proportions for BN, SF and PPF are shown in Table 4.

Table 4: Mix proportions used in the study

Mix ID	Bentonite (%)	Silica Fume (%)	PPF (%)
Control Mix	0	0	0
(BN-0, SF-5, PPF-0.75)	0	5	0.75
(BN-0, SF-5, PPF-1)	0	5	1
(BN-0, SF-5, PPF-1.25)	0	5	1.25
(BN-5, SF-5, PPF-0.75)	5	5	0.75
(BN-5, SF-5, PPF-1)	5	5	1
(BN-5, SF-5, PPF-1.25)	5	5	1.25
(BN-15, SF-5, PPF-0.75)	15	5	0.75
(BN-15, SF-5, PPF-1)	15	5	1
(BN-15, SF-5, PPF-1.25)	15	5	1.25

2.3 Methodology of Research

The weight of all ingredients of concrete was done accurately to ensure consistency. A concrete mixer delivered uniform mixtures while operating at 30 revolutions per minute as a steady speed. Each mix received uniform mixing processing that took place at a constant duration. The mixers received dry ingredients as its initial component. First of all, sand was placed, then coarse aggregate and binders were added. The addition of PP fibers occurred at the final stage of mixing to stop the fibers from clumping because of mixing vortex strength increases. The sample moulds received

freshly prepared concrete to fill them. Three test samples were made to achieve an average reading value during the analysis. Concrete fresh property was measured through slump test conforming ASTM C143 procedure [19]. A standard slump cone measuring 200 mm in base diameter and 100 mm in top diameter and 300 mm in height was kept on a rigid surface for stability. The concrete mixture was added to the cone in three equal portions before compacting each layer 25 times with a tamping rod for uniform density. After leveling the top surface, the cone was carefully lifted vertically within 5 to 10 seconds without twisting or tilting, allowing the concrete to subside naturally. The slump was determined by measuring the vertical distance between the initial cone height and the final concrete settlement point. The research evaluated compressive strength through analysis of 150 × 150 × 150 mm concrete cubes per BS EN 12390-3 [20]. The compressive strength test was conducted to determine the load-bearing capacity of hardened concrete. Standard concrete cubes of 150 mm × 150 mm × 150 mm were prepared and cured in water at a temperature of 20 ± 2°C for the curing period of 28 days. The testing process began after cubes were taken from their curing tank and allowed to dry. The compression testing machine received each specimen in its central position to apply uniform axial loading. The test was conducted using a constant loading rate of 0.6 ± 0.2 MPa/s until the cube failed. The maximum load at failure was recorded and divided by the cross-sectional area to determine the compressive strength. The results were expressed in megapascals (MPa).

9. Results and Discussion

9.1 Slump Test:

The slump test was performed according to ASTM C143 standards in order to determine the workability of concrete mixes. Control mix exhibited highest slump value of 76 mm, as it contained no supplementary cementitious materials (SCMs) or polypropylene fibers (PPF), allowing free water to remain available and ensuring unobstructed aggregate movement. The slump value reached 52 mm in the BN-15%, SF-5% and PPF-1.25% mixture which led to a 31.58% reduction in workability from the control mix. Bentonite's small particle size which increases surface area caused increased water requirements to create dense pastes that improved cohesiveness and reduced workability [23]. Because of its ultrafine size and large surface area silica fume further strengthened this impact while simultaneously boosting water use and resulting in a more compact mixture. Bentonite combined with silica fume in concrete decreased workability because of the finer particles. The workability of the mix decreased when PPF dosage became higher because the fibers created interconnected structures which restricted aggregate motion while raising internal friction. Enhanced fiber bridging effects led to greater slump reduction as PPF content in the mix increased from 0.75% to 1.25% which restricted the mix's free flowing capability.

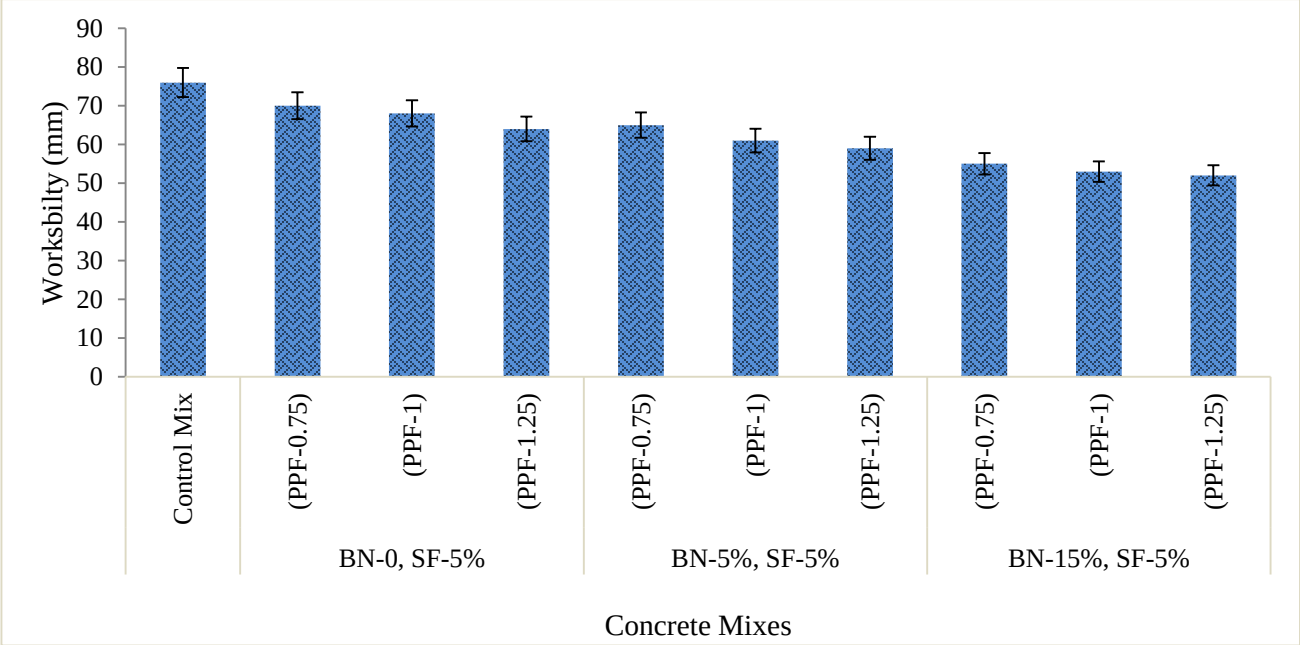

Figure 1: Slump Test Results

3.2 Compressive Strength

The ASTM C39 standard was used to measure the compressive strength of concrete cubes measuring 150 mm×150 mm× 150 mm concrete cubes. The control mix had the lowest compressive strength of 20 MPa. In the BN-0, SF-5% mixes (no bentonite), compressive strength improved with increasing PPF dosage up to 1%, where the highest was 24.75 MPa (23.75% greater than the control mix). Yet, for PPF-1.25%, the strength dropped slightly to 23.78 MPa, showing that higher fiber content resulted in agglomeration of fibers and lower bond strength in the matrix. Likewise, compressive strength in the BN-5%, SF-5% mixes also varied in the same manner, growing with increasing content of PPF up to 1%, recording the highest at 24.78 MPa (23.9% increment from the control mix). Yet, at PPF-1.25%, strength reduced to 23.65 MPa, reaffirming that an overabundance of fibers tended to destroy the matrix integrity. In the BN-15%, SF-5% mixes, compressive strength was less than BN-0 and BN-5% mixes, with the highest strength being 21.36 MPa at PPF-1% (6.8% more than the control mix). The general decrease in strength is due to the increased bentonite content (15%), which decreases cementitious material availability, resulting in a weaker matrix. Excess bentonite increased void formation and decreased interparticle bonding, which affected compressive strength adversely. The results revealed that best combination for compressive strength gain was BN-5%, SF-5% and PPF-1%, which showed the highest strength compared to the control mix. The concrete strength grew higher due to bentonite filler combined with pozzolana reaction properties that resulted in compacted refined concrete microstructures [24].

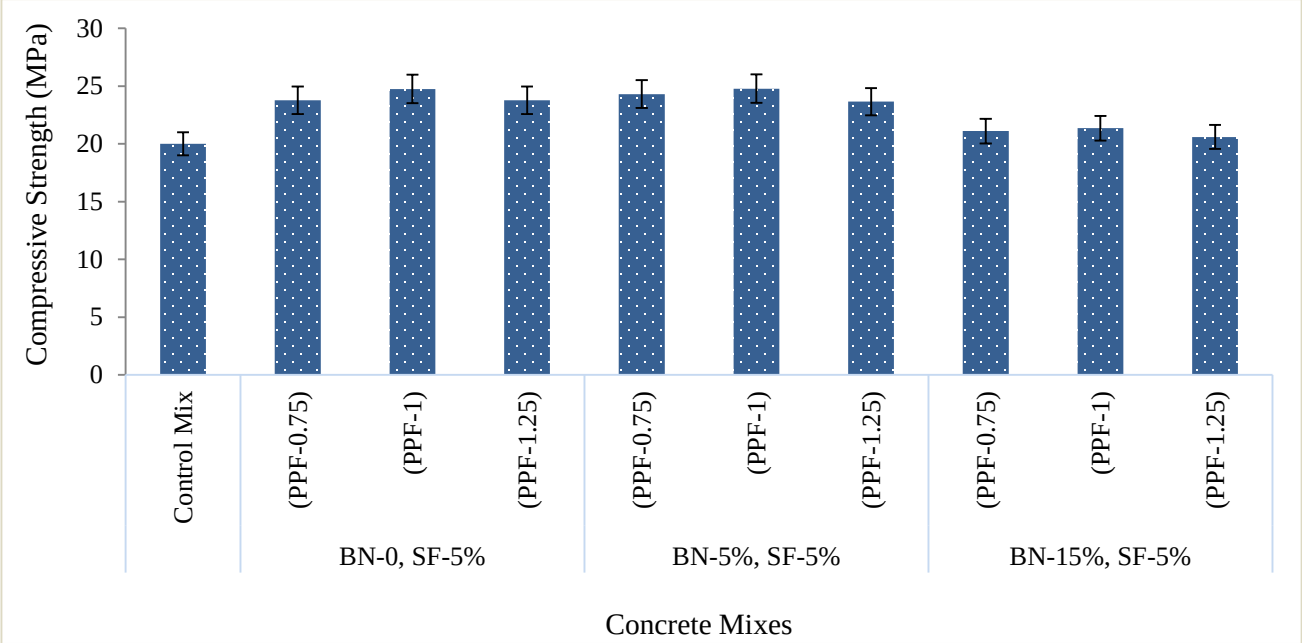

Figure 2: Compressive Strength Test Results

10. Conclusion

The current research evaluated the workability and compressive strength after adding bentonite, SF and PPF in concrete mixture. It was noted that, workability of all mixtures reduced with the inclusion of bentonite, SF and PPF in concrete. Minimum slump (52 mm) was obtained for BN-15%, SF-5%, PPF-1.25%, with 31.58% decrease from the control mix. The highest content of bentonite (15%) produced the greatest slump reduction. Increasing PPF dosage resulted in in further decrease of workability. BN-5%, SF-5% and PPF-1% mix had maximum compressive strength (24.78 MPa), 23.9% more than the control mix. Incorporation of PPF content up to 1% improved strength but at PPF-1.25%, it decreased because of fiber agglomeration and weak bond strength. Higher bentonite content (15%) lowered compressive strength. Test results showed that mixes with 5% bentonite improved strength while increased bentonite content (15%) caused decreased strength, proving that high bentonite weakens the cementitious matrix.

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Subject: Structural and Geotechnical Engineering

Theme: Foundations and Soil-Structure Interaction

Ref: 1st ICSIID//KHP/28

"Improving the Subgrade Soil Stability by Adding Lime Gypsum and Brick Ballast"

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ABSTRACT: Subgrade soil stability plays a crucial role in the durability and performance of road and pavement structures. Weak or unstable subgrade soil can lead to pavement failures, excessive settlements, and reduced load-bearing capacity. This study investigates the improvement of subgrade soil stability by incorporating lime, gypsum, and brick ballast in different proportions. The experimental analysis involves three mix ratios: **(6:2.5:10), (8:5:20),** and **(10:7.5:30),** where lime, gypsum, and brick ballast are added to the soil. Various geotechnical tests, including compaction and Atterberg limit tests, are conducted to evaluate the enhancements in soil consistency and plasticity characteristics. The results indicate that the addition of lime and gypsum improves soil cohesion and reduces plasticity, while brick ballast enhances soil structure by increasing particle interlocking. This study demonstrates that optimizing the mix proportions of these stabilizing agents can significantly improve the engineering properties of subgrade soil, making it a viable technique for sustainable and cost-effective soil stabilization in construction projects.

Keywords: Subgrade Soil, Soil Stabilization, Lime, Gypsum, Brick Ballast, Atterberg Limits, Soil Improvement, Pavement Performance, Engineering Properties.

1. Introduction

Subgrade soil stability is a fundamental factor in the long-term performance of roads, pavements, and other civil engineering structures. Weak or expansive subgrade soil can lead to structural failures, excessive settlements, and maintenance challenges, ultimately increasing construction and repair costs [1]. Improving the engineering properties of subgrade soil is essential for ensuring the durability and load-bearing capacity of infrastructure [2]. Soil stabilization is a widely used technique to enhance the strength and stability of weak soils by incorporating stabilizing agents [3]. Among various stabilizers, lime, gypsum, and brick ballast have proven effective in modifying soil properties [4]. Lime enhances soil strength by reducing plasticity, increasing shear strength, and promoting pozzolanic reactions that result in long-term strength gain [5]. Gypsum contributes to soil improvement by regulating moisture content and reducing soil shrinkage and expansion [6]. Brick ballast, a coarse aggregate, enhances soil stability by improving gradation, increasing interlocking between particles, and distributing loads more effectively [7].

This study aims to analyze the effects of lime, gypsum, and brick ballast on subgrade soil stability using three mix ratios**: (6:2.5:10), (8:5:20)**, and **(10:7.5:30).** Laboratory tests such as compaction and Atterberg

limit tests are conducted to evaluate the impact of these additives on soil plasticity and consistency [8]. The findings of this research will provide insights into optimizing subgrade soil stabilization techniques for improved pavement performance and sustainable construction practices [9].

2. Materials and Methodology

2.1 Atterberg Limits

The Atterberg limits, including the liquid limit and plastic limit, are essential tests to evaluate the consistency and plasticity characteristics of subgrade soil. These tests were conducted as per **IS 1498** and **IS 2720 (Part 5)** standards. The liquid limit test was performed using the **Casagrande apparatus**, where the number of blows required to close the groove was recorded to determine the moisture content at which soil changes from a liquid to a plastic state. For the plastic limit test, soil samples were rolled into thin threads of **3 mm** diameter on a glass plate until they crumbled.

To assess the impact of stabilizers, lime, gypsum, and brick ballast were added in varying proportions to the soil. The changes in liquid and plastic limits were recorded to analyze improvements in soil workability and plasticity. The reduction in plasticity index due to these additives indicated a significant improvement in soil stability, making it more suitable for subgrade applications.

3. Results and Discussion

3.1 Atterberg Limits

The Atterberg limits, which include the liquid limit and plastic limit, are essential indicators of soil consistency and plasticity. These limits determine how the soil transitions between liquid, plastic, and solid states, influencing its stability as a subgrade material.

The liquid limit test was conducted to assess the moisture content at which soil changes from a liquid to a plastic state. As shown in the table, the liquid limit of the natural (unstable) soil was **39.05%.** With the addition of lime, gypsum, and brick ballast in different ratios, the liquid limit decreased progressively, reaching **25.4%** in the 3rd ratio **(10:7.5:30).** This reduction indicates an improvement in soil workability and a decrease in moisture susceptibility.

Similarly, the plastic limit measures the moisture content at which soil transitions from a plastic to a semi-solid state. The plastic limit of the natural soil was **11.9%,** which increased with stabilization, reaching **19.6%** in the 3rd ratio. The increase in plastic limit, along with the decrease in liquid limit, resulted in a reduced plasticity index (PI = Liquid Limit - Plastic Limit), signifying better soil stability and reduced swelling potential.

These changes can be attributed to the flocculation and aggregation effect of lime and gypsum, which modify the soil structure by reducing clay content and enhancing soil strength. The decrease in plasticity makes the soil more suitable for construction as a subgrade, improving its load-bearing capacity and reducing shrink- swell behaviour. The vales of Atterberg Limits are given below in **Table 1:**

Table 1: Atterberg limit Values

Sample	LL	PL	PI
Expansive soil	39.05%	11.9%	27.15
1st Ratio (6:2.5:10)	33.12%	18.3%	14.82

2nd Ratio (8:5:20)	29.07%	20%	9.07
3rd Ratio (10:7.5:30)	25.4%	19.6%	5.8

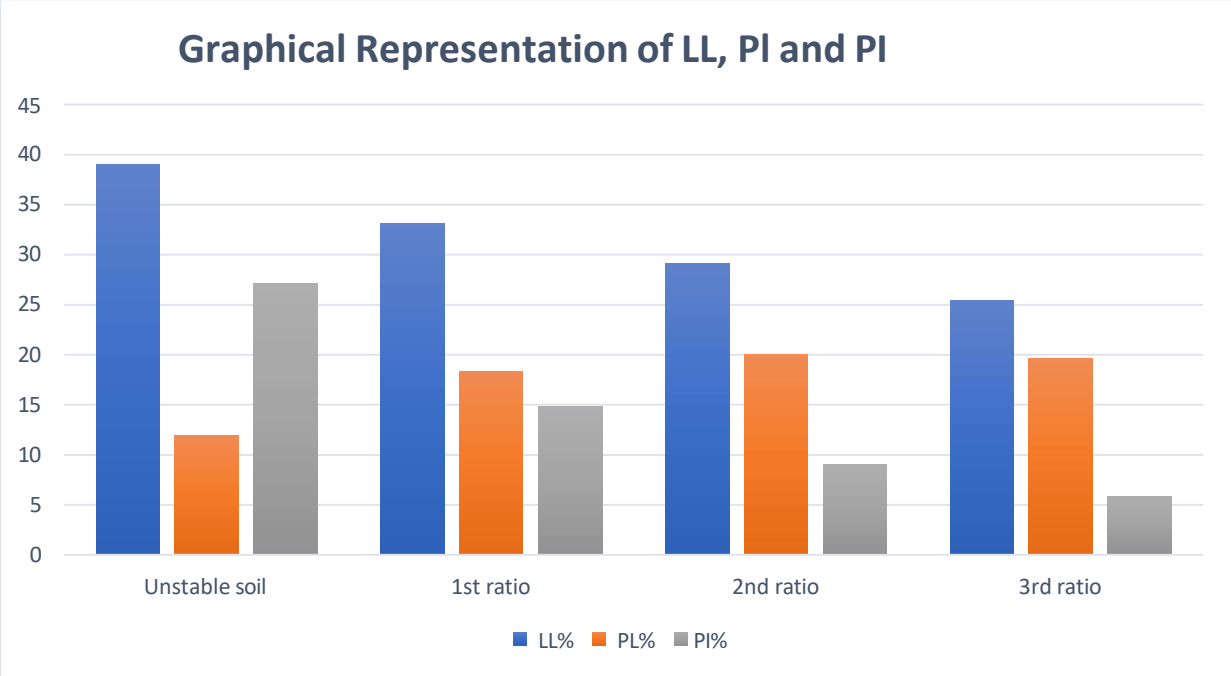

Figure 1: Graphical Representation of LL, PL and PI

4. Practical Implementation

This study focuses on improving subgrade soil stability by incorporating lime, gypsum, and brick ballast. The experimental results from the Atterberg limits test highlight the effectiveness of these stabilizing materials in enhancing soil performance.

1. Road Construction:

Reduced plasticity and improved moisture stability from the Atterberg limits test suggest better workability and reduced shrink-swell behavior, preventing pavement failures.

2. Foundation Stabilization:

Lime and **gypsum** improve soil cohesion, reducing settlement and increasing the bearing capacity of foundations.

3. Brick ballast enhances compaction, ensuring long-term stability for structures built on expansive or weak soils.

4. Embankments and Earthworks:

The **combination** of lime and gypsum minimizes water retention, reducing the risk of slope failures in embankments.

5. Airfields and Pavements:

The improved soil properties from the Atterberg limits test contribute to better workability and long-term

stability, making the stabilized soil suitable for airport runways and reducing maintenance costs.

6. Rural and Low-Cost Infrastructure:

The use of locally available stabilizers like lime, gypsum, and brick ballast makes the technique cost-effective for rural roads and low-cost housing projects.

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Innovative Integration of Shear Walls and bracings in High Seismic Performance Steel Frames for Enhanced Lateral Stiffness

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Abstract

This paper investigated the influence of bracing systems and shear walls on the seismic performance of high-rise steel buildings. Five building models were analyzed using ETABS software, considering a 20-story building with various configurations: no lateral resisting system, V bracings, X bracings, a taller building with X bracings (40 stories), and a combined system with X bracings and shear walls (40 stories). The analysis focused on story drift, displacement, and stiffness, aiming to understand how these elements improve a structure's ability to withstand lateral seismic loads.

The results revealed that both V and X bracing systems significantly reduced story drift and displacement compared to a building lacking lateral resistance. The combined system of X bracings and shear walls exhibited the lowest story drift and displacement, demonstrating its effectiveness in minimizing lateral movement. Similarly, story stiffness increased considerably with the inclusion of bracing systems and shear walls, with the combined system offering the greatest improvement. These findings support the project's objectives of analyzing bracing system performance and developing novel shear wall integration for enhanced structural integrity.

Keywords: High Seismic Performance, Shear Wall density, Bracing and Steel Frame

11. Introduction

Metal Shear Panels (MSPs) are increasingly used in steel structures to resist seismic forces. The study "Comparing Performance of Braced Circular Grid Panels and Braced Rectangular Thin Panels" done by (Arshana & Anishma, 2023) compares the seismic performance of Rectangular Braced Ductile Thin Shear Panels (BDSP) with a novel configuration called Combined Braced Circular Damped Grid Panels (BCDP). BCDP replaces BDSP's rectangular panels with concentric circular grids. It is hypothesized that the circular grids absorb load under reverse cyclic loading, enhancing seismic capabilities. ANSYS software is utilized for parametric studies, seismic, and pushover analyses. BCDP surpassed BDSP in seismic performance, showing no buckling failure.

The ideal BCDP model had three 20mm connection plates, highest load capacity. BCDP exhibited greater ductility and yield displacement, indicating improved seismic stability.

Another piece of art made by (Ghamari & Naeimi, 2023) on “Investigating the seismic behaviour of high-performance steel plate shear walls” that High-Performance Steel Plate Shear Walls (HPSPSWs) offer advantages over traditional Steel plate shear wall (SPSWs) by eliminating the need for large surrounding columns. Comparative analysis shows that HPSPSWs exhibit favorable stiffness, ductility, and energy absorption when the length-to-height ratio exceeds 1.5. Despite a slight reduction in ultimate lateral strength compared to SPSWs, HPSPSWs maintain comparable performance. With modification factors suggesting an optimal value of 8.5, HPSPSWs present promising economic and structural benefits for seismic-resistant building design.

Steel Plate Shear Walls (SPSWs) are known for their robust lateral load resistance and effective energy dissipation under seismic loads. The study made by (Ghafar et al., 2022) on “Seismic performance investigation of an innovative steel shear wall with semi-rigid beam-to-column connections” investigates the seismic performance of an innovative Infill Web Strip (IWS-SPSW) compared to a conventional Unstiffened Steel Plate Shear Wall (USPSW). Experimental results show that the IWS-SPSW exhibits outstanding ductility, shear load-bearing capacity, and energy dissipation without damage, whereas the USPSW demonstrates excellent shear load-bearing capacity but lower ductility and extensive corner tearing of the infill plate. These findings suggest the potential of the IWS-SPSW to enhance structural resilience against seismic forces.

Shear wall systems are widely utilized for lateral-load resistance in high-rise buildings, with composite steel plate shear wall (CSPSW) systems gaining popularity due to their high bearing capacity, ductility, and energy dissipation capabilities. This study “Cyclic behavior of SPSW and CSPSW in composite frame” concluded by (Guo et al., 2012) presents experimental tests of steel plate shear wall (SPSW) and CSPSW systems using 1/3 scaled specimens. The results demonstrate that both systems exhibit good ductility and energy dissipation capacity. Additionally, the CSPSW system shows enhanced bearing capacity and energy dissipation compared to the SPSW system. However, the CSPSW system exhibits more pronounced out-of-plane deformation of the steel plate at higher storey drift ratios, leading to specific failure modes.

The steel tube-reinforced concrete (STRC) shear wall, a composite structure combining reinforced concrete shear walls with high-strength concrete-filled steel tube (CFST) columns, has become popular in high-rise construction for its superior performance over conventional reinforced concrete (RC) walls. This study was compiled by (Zhou et al., 2018) On “Mechanical behavior of a steel tube-confined high-strength concrete shear wall under combined tensile and shear loading”, explores the mechanical properties of STRC shear walls under combined tension and shear forces, considering factors like the number of CFSTs, shear span ratio, vertical reinforcement ratio, concrete strength outside the steel tube, and initial tensile stress. Tensile shear tests on nine specimens reveal that STRC shear walls maintain high shear capacity and ductility even under significant axial tensile forces, demonstrating robust bearing capacity under tensile shear loading, including high initial tensile loading where steel bars yield to tension. These findings highlight the resilience and effectiveness of STRC shear walls in high-rise construction.

A study was conducted by (Autade, 2021) to analyze the seismic response of 12 structural models incorporating various forms of bracing and soil types. These models included X, V, and Y bracing configurations, with and without Buckling-Restrained Braces (BRBs), across three soil types: sand, silt, and clay. Utilizing ETABS17 and linear dynamic analysis, the seismic performance of multi-story steel frames in seismic zone 4 was investigated.

The results highlighted significant variations in structural characteristics such as story displacement, drift, stiffness, and shear in response to seismic forces and soil type. Notably, the presence of BRBs notably improved the structures' ability to withstand distortion. Analysis revealed that X bracing, particularly in clay and sandy soil, reduced story displacement by 30%, outperforming V and Y bracing configurations. Comparisons of base shear interactions between soil-structure systems indicated variations ranging from 15% to 20%, emphasizing the importance of considering soil-structure interaction (SSI), especially in multi-story buildings and poor soil conditions.

Furthermore, analyses of story drift variations underscored the significance of SSI in mitigating drift in taller structures and weaker soils. The study concluded that X bracing showed the most promising performance across different soil types. Additionally, the study observed a 16% increase in self-weight deformity due to soil-structure interactions. Overall, the analysis suggested that X bracing outperformed V and Y bracing configurations, with soil-structure interaction providing valuable insights into the behavior of the frame system.

Another study “Modelling of Bracing Systems for Seismic Behaviour of High-Rise Steel Building” investigates the seismic behavior of high-rise steel buildings with various bracing systems through non-linear static analysis. Bracing systems including V-Braced frames (VBF), Chevron Braced frames (CBF), X-Braced frames, and Self-centering energy dissipating braced frames (SCEDBF) were evaluated across heights ranging from 10 to 35 storeys. Results show that braced frames outperform moment resisting frames in terms of storey displacement, inter-storey drift ratio, base shear capacity, and performance point. Specifically, VBF and CBF exhibit similar performances, as do XBF and SCEDBF.

The study emphasizes the importance of bracing systems in dissipating seismic energy and highlights their role in enhancing structural performance. Non-linear pushover analysis was employed to assess seismic response parameters, revealing that buildings with bracing systems experience lower roof displacement compared to moment resisting frames (Rishad & Singh, 2023). Additionally, it was observed that the sequence of failure in braced buildings differs from moment resisting frames, with plastic hinge formation starting at the brace, then the beam, and finally the column. The seismic behavior of buildings is significantly influenced by building height and lateral load patterns.

12. Materials and Methodology

How we can achieve Lateral stiffness.

A) By Bracings

Braced frame system in the structure consists of truss members as bracing elements. These bracings are commonly used in structures, subjected to lateral loads. They resist lateral forces mainly with the brace members in compression or tension. This makes the bracing system highly efficient in resisting the lateral loads. In addition, another reason for the braced frame system to be efficient is, it makes the structure laterally stiff. With least addition of the material to the frame and it forms economical structure for any heights.

B) By Circular steel tubes.

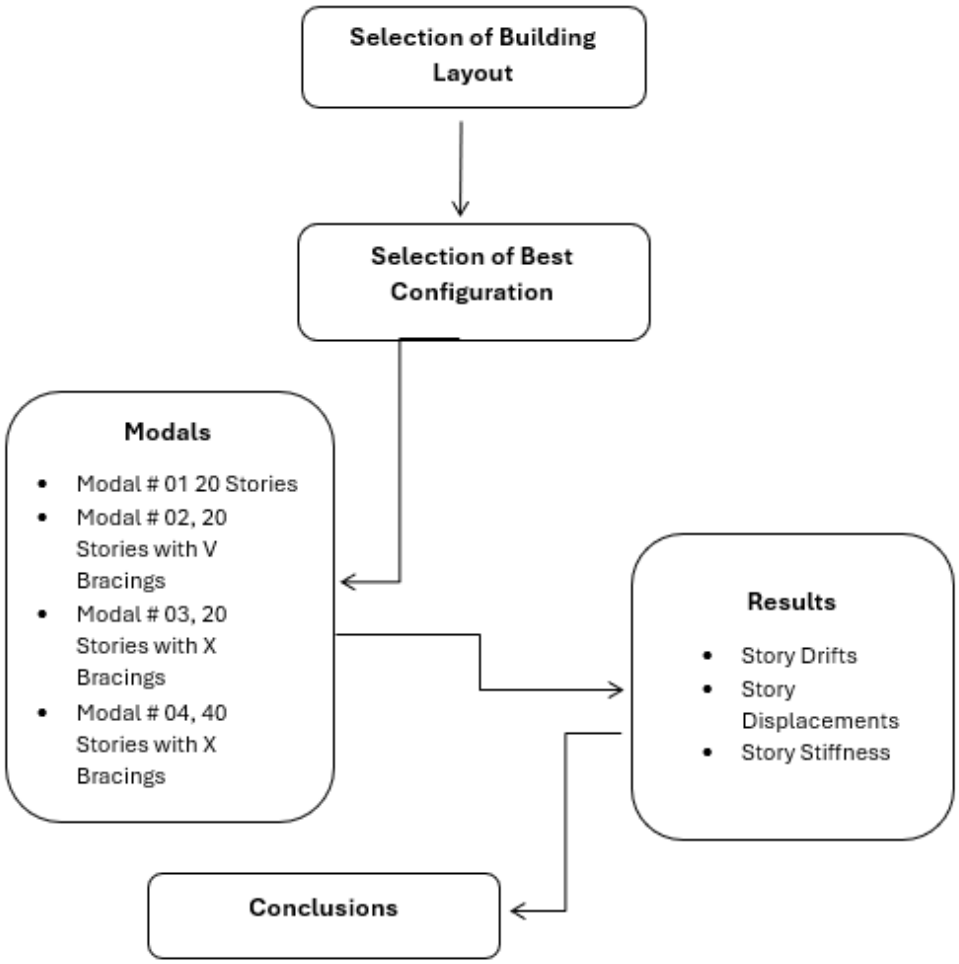
Using circular steel tubes or double steel circular sheets filled with concrete can be an effective way to enhance the lateral stiffness of high-rise buildings.

Empty tubes: Hollow circular steel tubes can provide some lateral stiffness due to their geometric shape and material properties. However, their effectiveness depends on factors like tube diameter, thickness, and material strength.

Concrete-filled tubes: Filling the tubes with concrete can significantly improve their lateral stiffness,

as the concrete provides additional strength and stiffness. The concrete infill also helps to resist compressive forces and buckling.
Steel sheets: Two concentric steel circular sheets can provide a high strength-to-weight ratio and good lateral stiffness due to their geometry and material properties.
Concrete infill: Filling the gap between the two steel sheets with concrete can further enhance the lateral stiffness, as the concrete provides additional strength and stiffness.

Methodology Flow Chart



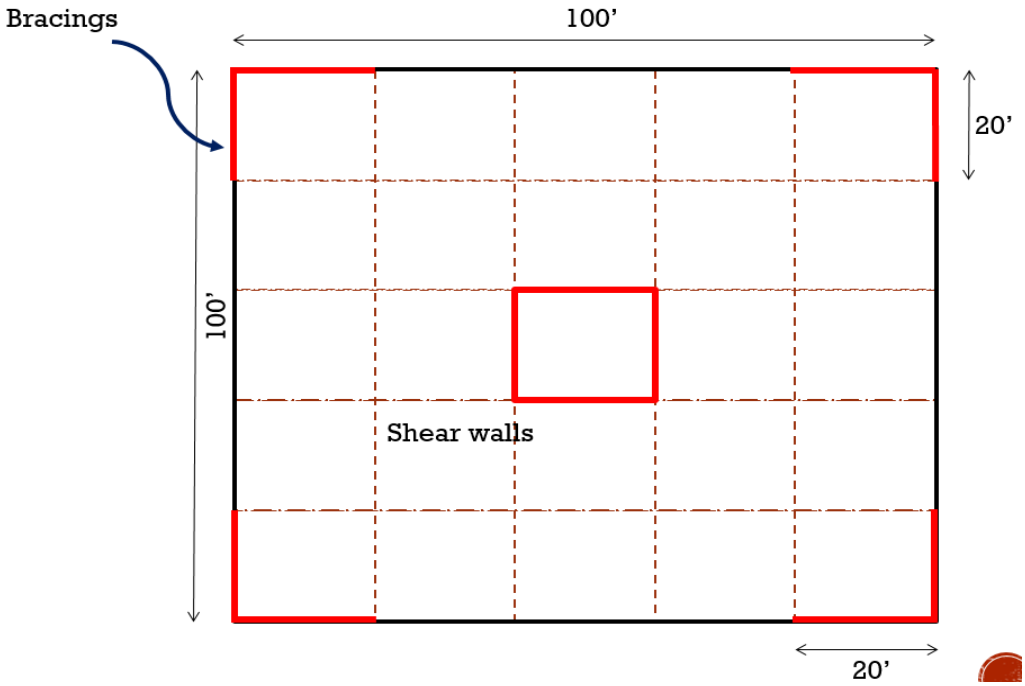


Figure 1: Building Layout Plan and Suitable Combination for Shear walls and Bracings

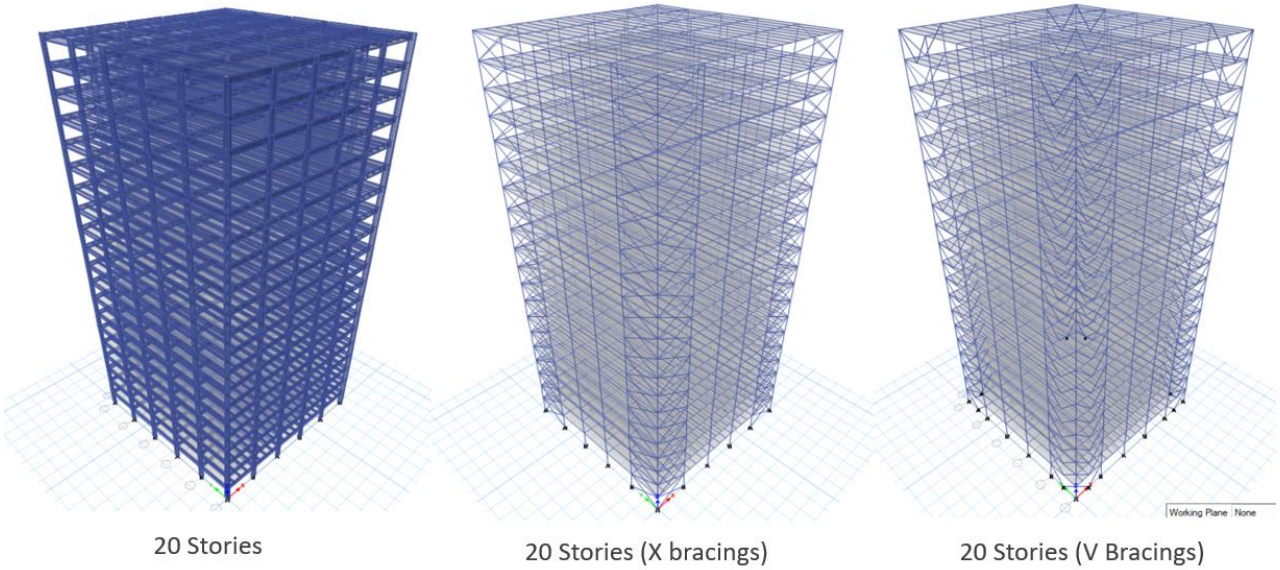


Figure 2: Etabs Models 20 Stories

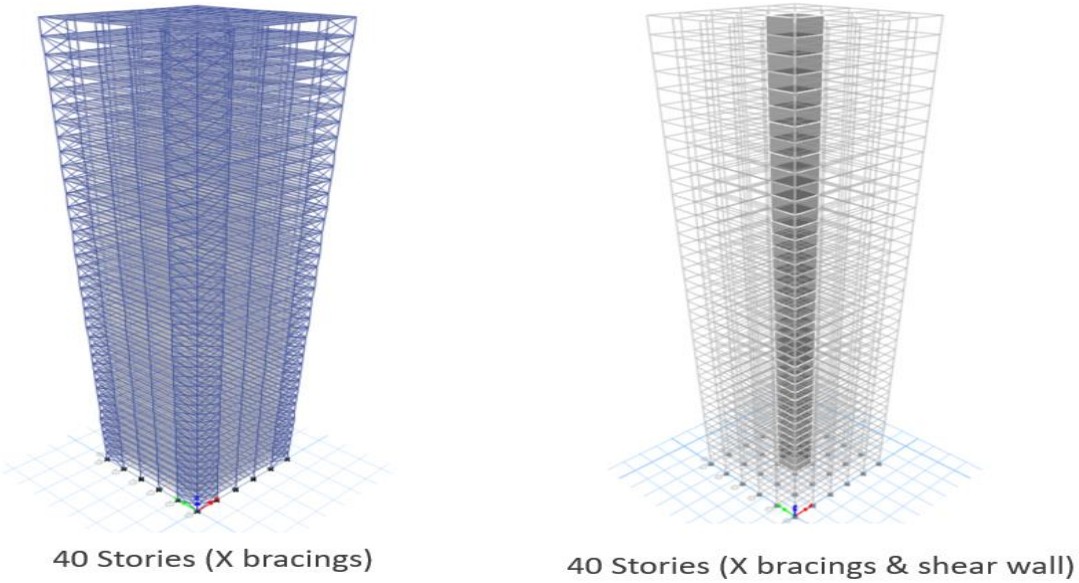


Figure 3: Etabs Models 40 Stories

Breakdown of Methodology

Building Parameters: The first step involves defining the building size, which in this case is 100'x100'. Other parameters include the seismic zone (4 in this case), potential bracing types (X, V, K and Chevron), shear wall configurations (single skin, double skin, concrete filled and FRP) and story heights (10, 20, 40 and 60 ft.).

Modal Selection: This step involves creating multiple models of the building with different configurations. The flowchart shows four models being analyzed:

- Modal #1: 20 stories
- Modal #2: 20 stories with V Bracings
- Modal #3: 20 stories with X Bracings
- Modal #4: 40 stories with X Bracings
- Modal #5: 40 stories with X Bracings and Shear Walls

ETABS Modeling: Each of the building configurations are then modeled using ETABS software, a popular tool for building analysis.

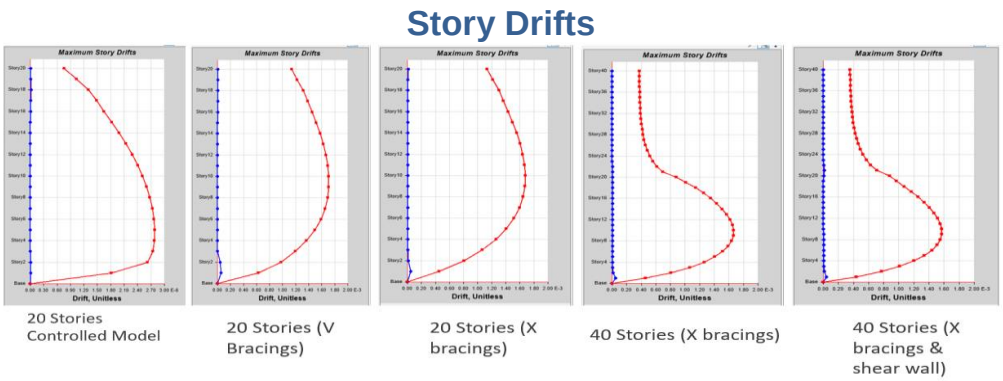
Analysis: The ETABS models are then analyzed to determine the following:

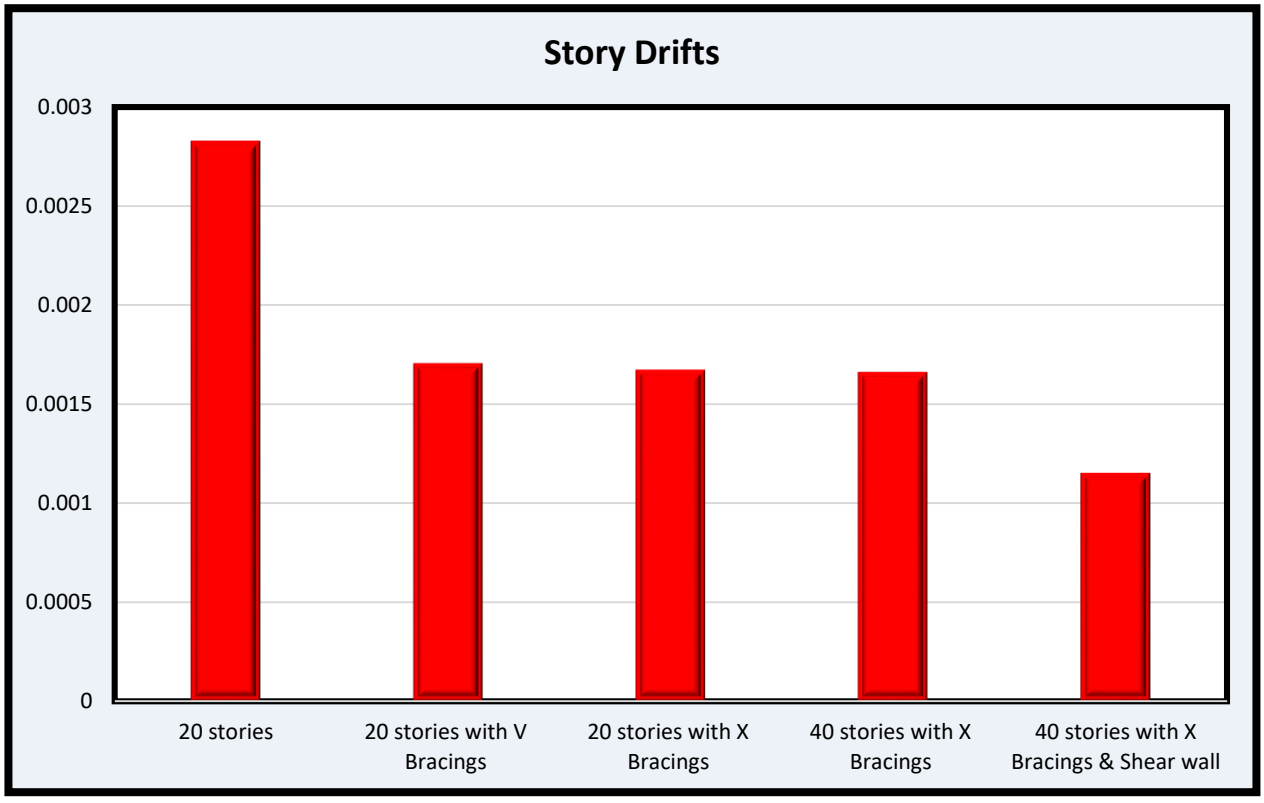
- Story drifts
- Story displacements

- Story stiffness

Evaluation and Conclusion: Based on the analysis results, the most suitable configuration for the building is selected. The flowchart uses the term “best configuration” but does not define what “best” means. It typically refers to a configuration that meets all the building code requirements while being the most cost-effective.

13. Results and Discussion



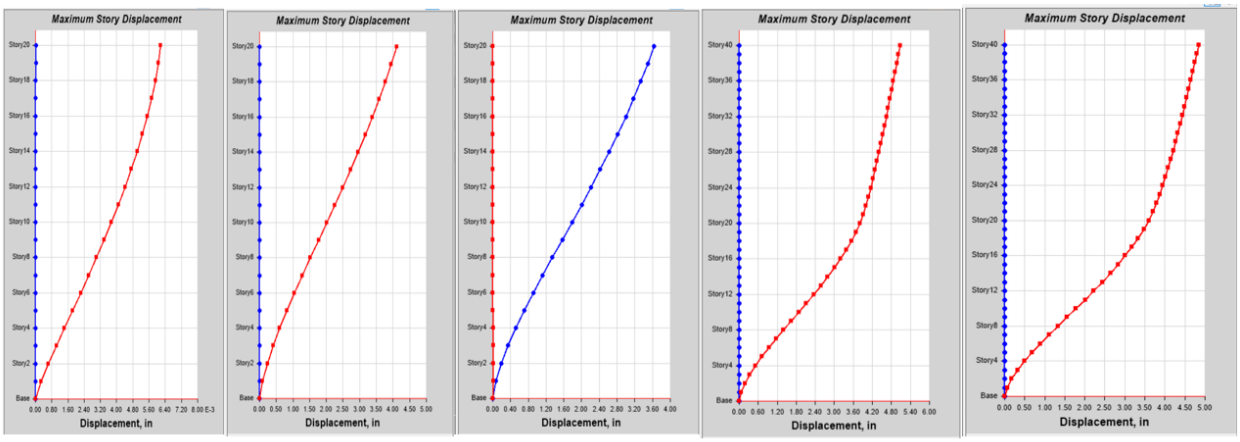


The analysis of the five building models in ETABS showed that the story drift is significantly reduced

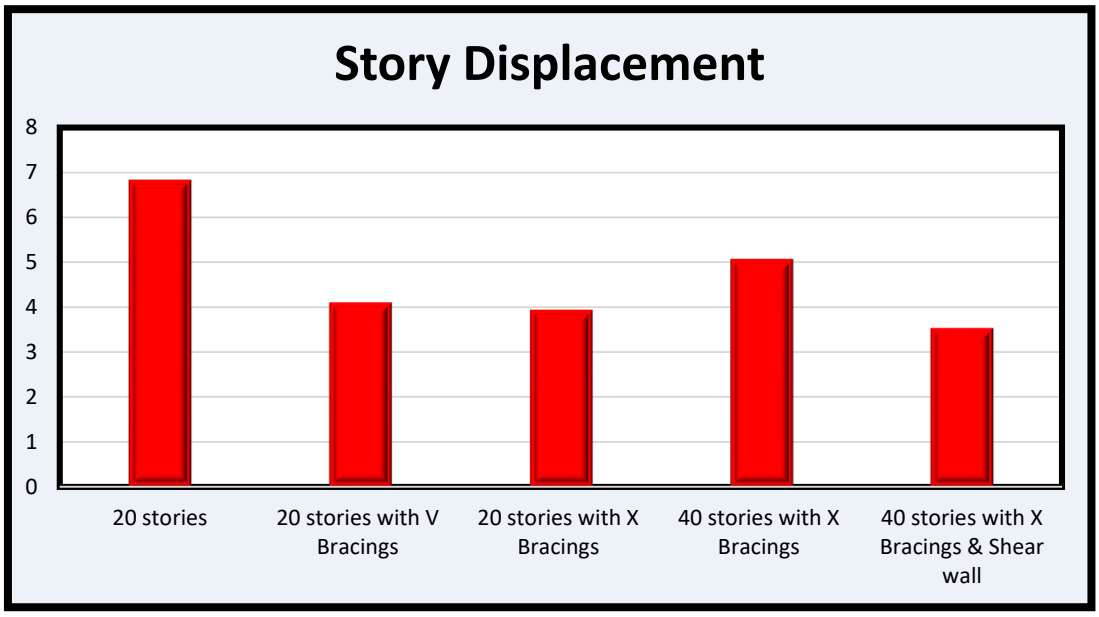
when using bracing systems and shear walls. Model 1, which is the 20-story building with no bracings or shear walls, has the highest story drift. This is to be expected, as there is nothing to stiffen the structure and resist lateral loads.
Model 2 (20 stories with V Bracings) and Model 3 (20 stories with X Bracings) both show a reduction in story drift compared to Model 1. This indicates that both V and X bracing systems are effective at reducing lateral movement in the building. However, it is difficult to say from this graph alone which type of bracing (V or X) is more effective.
Model 4 (40 stories with X Bracings) shows slightly more story drift than Model 3 (20 stories with X Bracings). This is likely because the taller building is more flexible and will experience greater lateral movement.
Model 5 (40 stories with X Bracings and Shear Walls) shows the least story drift. This is because the combination of X bracing and shear walls provides the stiffest lateral load resisting system of the five models analyzed.
Overall, the results from the ETABS analysis confirm that bracing systems and shear walls are effective at reducing story drift in high-rise buildings. The use of a combined bracing and shear wall system provides the most significant reduction in story drift.

Story Displacement

The analysis of the five building models in ETABS showed that using bracing systems and shear walls can significantly reduce story displacement. Model 1, the 20-story building with no bracings or shear walls, has the highest story displacement. This is expected because there is nothing to stiffen the structure and resist lateral loads.



20 Stories Controlled Model | 20 Stories (V Bracings) | 20 Stories (X bracings) | 40 Stories (X bracings) | 40 Stories (X bracings & shear wall)



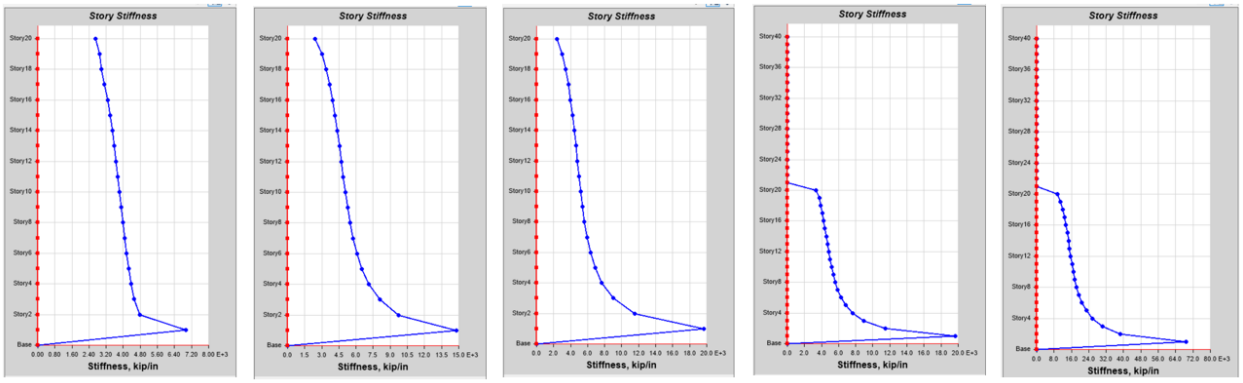
Model 2 (20 stories with V Bracings) and Model 3 (20 stories with X Bracings) both show a reduction in story displacement compared to Model 1. This indicates that both V and X bracing systems are effective at reducing lateral movement in the building. However, it is difficult to say from this graph alone which type of bracing (V or X) is more effective.

Model 4 (40 stories with X Bracings) shows slightly more story displacement than Model 3 (20 stories with X Bracings). This is likely because the taller building is more flexible and will experience greater lateral movement.

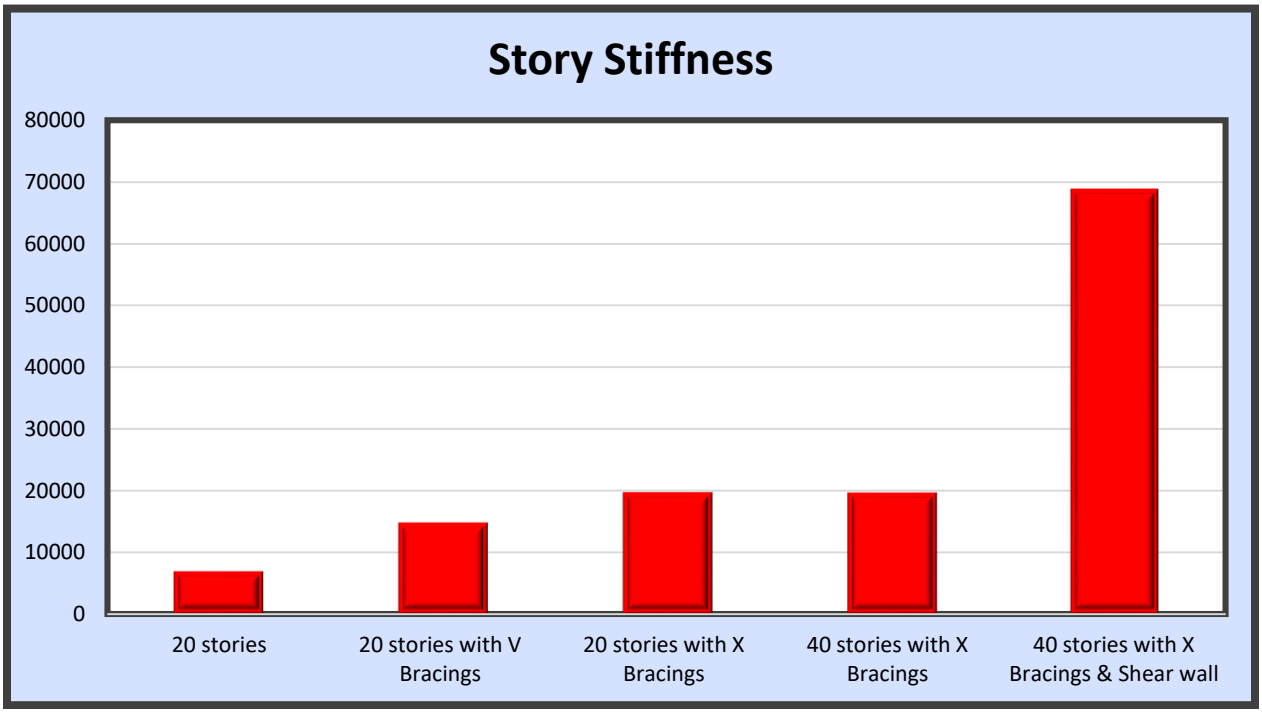
Model 5 (40 stories with X Bracings and Shear Walls) shows the least story displacement. This is because the combination of X bracing and shear walls provides the stiffest lateral load resisting system of the five models analyzed.

Overall, the results from the ETABS analysis confirm that bracing systems and shear walls are effective at reducing story displacement in high-rise buildings. The use of a combined bracing and shear wall system provides the most significant reduction in story displacement.

Story Stiffness



20 Stories Controlled Model | 20 Stories (V Bracings) | 20 Stories (X bracings) | 40 Stories (X bracings) | 40 Stories (X bracings & shear wall)



The analysis of the five building models in ETABS aimed to investigate the influence of bracing systems and shear walls on story stiffness, and to explore how these elements improve lateral load resistance. This is particularly relevant to the project objectives of analyzing the performance of bracing systems and investigating the integration of shear walls within high-performance steel frames.

As expected, Model 1 (20-story building with no bracings or shear walls) exhibits the least story

stiffness in the graph. This is because there is nothing to stiffen the structure against lateral loads.
Models 2 (20 stories with V Bracings) and 3 (20 stories with X Bracings) show a significant increase in story stiffness compared to Model 1. This indicates that both V and X bracing systems are effective at stiffening the structure. It is difficult to determine from this graph alone which type of bracing is stiffer (V or X).
Model 4 (40 stories with X Bracings) shows slightly less story stiffness than Model 3 (20 stories with X Bracings). This is likely because the taller building is more flexible and will have lower inherent stiffness.
Model 5 (40 stories with X Bracings and Shear Walls) exhibits the greatest story stiffness. This is because the combination of X bracing and shear walls creates the stiffest lateral load resisting system of the five models analyzed. This aligns with the objective of developing novel shear wall integration for enhanced structural integrity.
Overall, the ETABS analysis confirms that bracing systems and shear walls significantly improve story stiffness and lateral load resistance in high-rise buildings. The use of a combined bracing and shear wall system provides the most significant improvement in story stiffness.

14. Conclusion

Bracing systems (both V and X) and shear walls significantly improve a building's performance in resisting lateral loads from seismic events.
The combined use of X bracings and shear walls provides the most significant reduction in story drift and displacement, along with the highest story stiffness. This aligns with the project objective of developing solutions for enhanced structural integrity.
Further analysis might be needed to definitively determine the most efficient bracing type (V vs. X) for specific scenarios.
Structural Stability: The 40 stories building demonstrate excellent structural stability under seismic loading conditions. This means minimal lateral sway and deformation during earthquakes, ensuring occupant safety and comfort.
Seismic Performance: The combination of X bracing and shear walls effectively dissipate seismic forces, reducing building accelerations and minimizing structural damage.
Resilience: The structure demonstrate resilience by maintaining its integrity and functionality even after significant seismic events. This includes the ability to resist damage and continue to support loads, allowing for safe evacuation and post-earthquake occupancy.
Damping Effectiveness: The X bracing and shear walls have exhibited effective damping properties, dissipating seismic energy to reduce vibrations and mitigate structural damage. This is done through dynamic analysis, showing reduced peak accelerations and response spectra within acceptable limits.

Post Work

Performance-Based Design Philosophy: Highlight the shift towards performance-based seismic design, focus on achieving specific performance objectives rather than simply meeting prescriptive code requirements.
Nonlinear Analysis Techniques: such as pushover analysis and time history analysis, to assess the nonlinear behavior of the structure under seismic loading. valuable insights into factors such as strength degradation, stiffness softening, and energy dissipation mechanisms, which are critical for

accurately predicting seismic performance.

Base Isolation and Energy Dissipation Systems: integration of base isolation and energy dissipation systems to enhance the seismic resilience of the building. reducing seismic forces transmitted to the building, while energy dissipation systems absorb and dissipate seismic energy, mitigating structural response.

Probabilistic Seismic Hazard Assessment: Discuss the use of probabilistic seismic hazard assessment (PSHA) to quantify the seismic hazard at the building site in terms of ground motion intensity, recurrence intervals, and exceedance probabilities. This allows for a probabilistic evaluation of seismic performance, considering the uncertainties associated with earthquake ground motion and structural response.

Performance Metrics: drift limits, inter-story drift ratios, and acceleration thresholds, which serve as criteria for evaluating the seismic performance of the building.

Post-Earthquake Evaluation and Repair Strategies: This includes visual inspections, non-destructive testing techniques, and retrofitting measures to restore structural integrity and prevent future damage.

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Exploring the Fire Resistance of Coal Slurry Powder-Based Self-Compacting Concrete

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ABSTRACT: The present work examines the effect of temperature and the variation of the proportion of coal slurry (CS) with cementitious materials on the compressive strength characteristics of CS-SCC (self-compacting concrete). All concrete cylinders with and without CS replacement were exposed to temperatures ranging from 23°C to 900°C. The experimental procedure was conducted in two phases: phase one was to test the compressive strength of the normal SCC cylinders of size (0.15m x 0.30m) at normal and high temperatures and phase two was to examine the eighteen cylinders, containing 10%, 20%, and 30% CS replacement under similar thermal environments. Samples made from the cylinders were exposed to heat treatment from a furnace and then the cylinder was taken for a compressive strength test on a Universal Testing Machine (UTM). Significance level analysis revealed a decrease in the 7-day compressive strengths of the normal and treated samples. As for the normal SCC, the exposed compressive strength was reduced to 71% of the control value after exposure to 900°C. In like manner, the strength decrease across all replacement degrees of the CS-treated samples was about 72 percent. These results indicate that the addition of CS as cement replacement is only marginally comparable to the thermal degradation of normal SCC and therefore offers little advantage in high-temperature settings. Based on this study it is clear that CS substitution is possible but the structural characteristic inherent in exposure to higher temperatures should be further improved.

KEYWORDS: Self-compacting concrete, coal slurry, temperature, compressive strength, universal testing machine

1. Introduction

The behaviour of self-compacting concrete (SCC) at high temperatures is another important focus of research because of the growing concerns with sustainable and durable construction materials. Use of high-performance self-compacting concrete (HPSCC) Which is made through the incorporation of recycled aggregate concrete (RAC) and Waste Materials has demonstrated a positive impact for sustainable construction as well as thermal performance improvement. Abed and de Brito [1] affirmed that the residual compressive and flexural strength of HPSCC reduced with temperatures while it obtained enhancement in fire resistance with RAC and cement-replacement materials (CRMs) such as fly ash, perlite, and cellular. Further research has also pointed out that

RAC improves the mechanical properties of concrete after exposure to high temperatures attributable to its well-developed interfacial bond with the new matrix [2, 3]. Scientists have stressed the need to use CRMs, as their alkaline reaction makes them contribute to the formation of a dense interfacial transition zone which enhances the residual characteristics of concrete after fire exposure, [4, 5].

Ultrasonic pulse velocity (UPV) is one of the attractive residual strength evaluators which are conducted non-destructive in nature as they can provide quick results. Omer et al. [6] observed that the relationship between the residual compressive strength and UPV in the geopolymer mortars increased exponentially with exposure to higher temperatures. Likewise, Chung [7] noted that UPV values reduce with rising temperature thereby making it suitable to determine the internal condition of concrete. Sarhat and Sherwood [8] supported this by showing that while RAC has an alarmingly lower UPV than new natural aggregate concrete, the inclusion of CRMs helps overcome this by improving the bond between the new mortar and RAC [9]. The introduction of Silica fume, metakaolin, and Ground granulated blast furnace slag has also been found to enhance the thermal and mechanical performance of SCC particularly when exposed to high-temperature conditions [10, 11].

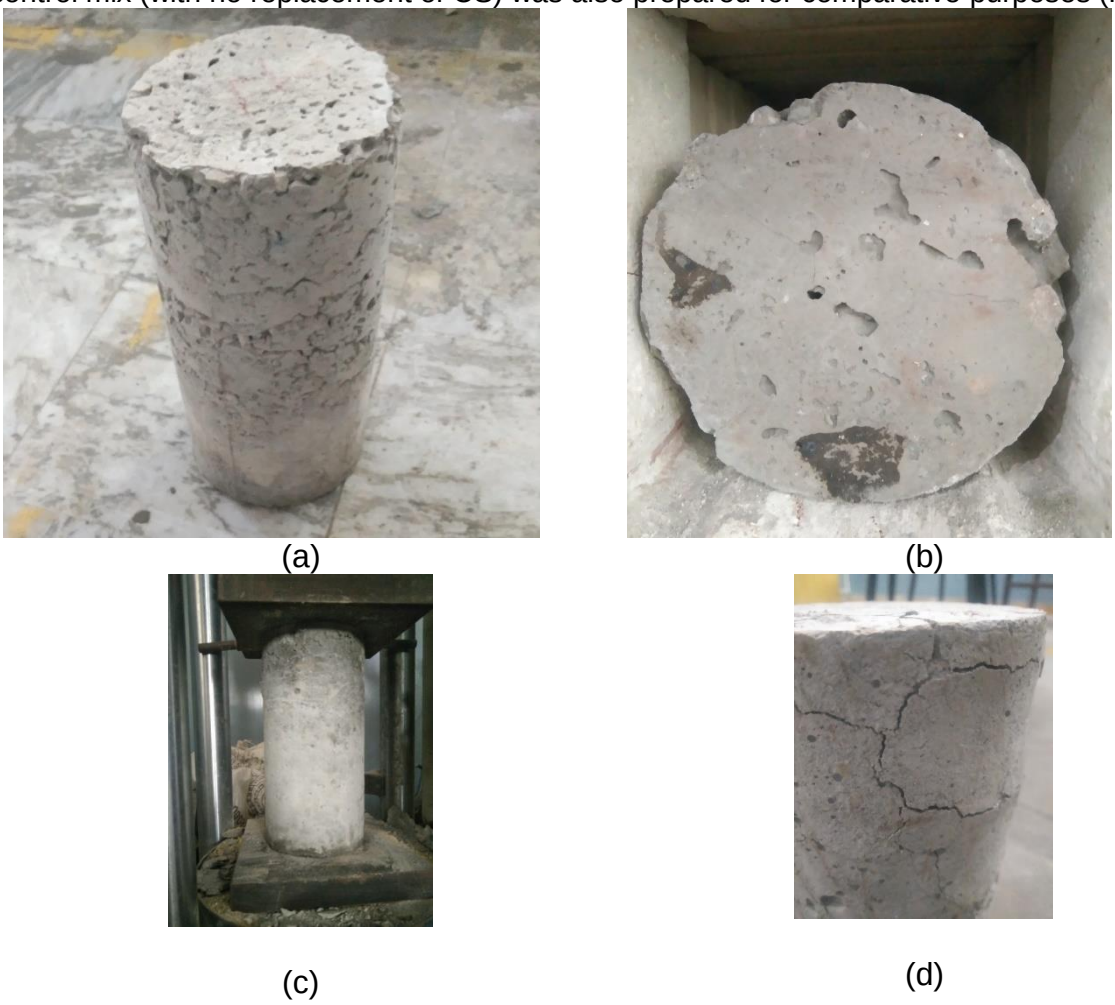
At raised temperatures concrete mechanical properties are a function of the thermal properties of the individual constituents. When applied in SCC the use of RAC causes the potential for explosive spalling to be reduced something familiar with normal concrete [12]. Similar to the earlier RAC investigations of Vieira and Braga and co-workers, RAC was also found to exhibit high residual properties up to 800°C in the investigations carried out by Laneyrie and co-workers. The thermal performance of SAHs is also improved with the help of CRMs, as Identified by Khaliq and Taimur [15] and Pathak and Siddique [16]. Further, while the fine-grained microstructure of SCC is beneficial during normal temperature operations, it is detrimental to the material's high-temperature capability in terms of spalling propensity [17]. This has led researchers like Yang et al. [18] and Belaribi et al. [19] to develop empirical relationships that help in estimating the residual properties of concrete through UPV and are very important in assessments of fire-damaged structures. Overall, HPSCC produced with sustainable materials demonstrates considerable potential for applications requiring fire resistance and environmental benefits [20]. Self-compacting concrete (SCC) experiences a severe degradation of its compressive strength at high temperatures, restricting its use where heat effects are anticipated. The main aim of this study was to assess the performance of partially replacing cement with coal slurry (CS) on the compressive strength of self-compacting concrete (SCC) at different temperatures. The research tries to establish the thermal resistance of SCC with 10%, 20%, and 30% CS replacement against normal SCC, and evaluate the decrease in strength of the concrete at temperatures ranging from 23°C-900°C. Based on these areas, the research aimed at establishing the possibility of using CS as an important primary substitute for SCC that is subjected to high-temperature conditions.

1. Materials and Methodology

The specific objectives of this work are to examine the compressive strength characteristics of self-compacting concrete (SCC) which has been subjected to thermal treatment and in which coal slurry (CS) has been used as cement replacement material to a certain extent. The experimental program was divided into two phases as intended to investigate the impact of temperature and CS replacement percentage on the concrete compressive strength (Figure 1).

2.1 Materials and Mix Design

The constituents that were used in the formulations of the SCC included OPC, fine aggregates, coarse aggregates, and water with coal slurry as cement replacing material. The mix design followed a ratio of 1:1.5:1.5:cement to fine aggregate and cement to coarse aggregate ratios were 5:1.5 and the w/c ratio was 0.40 (Table 1). Both longitudinal and transverse orientation was used for all experimental tests of cylindrical specimens with the following dimensions 0.15 m diameter by 0.30 m height. To evaluate the effects of CS replacement, three different substitution levels of cement with coal slurry were implemented: by weight of cement is 10%, 20%, and 30% respectively. A control mix (with no replacement of CS) was also prepared for comparative purposes (Figure 1a).



(a) (b) (c) (d)

Figure 1. Laboratory procedure of the current research methodology (a) prepared sample (b) heating process (c) compressive strength (d) sample tested for compressive strength.

2.2 Preparation of Specimens

These materials were well blended to achieve good compaction and workability of the concrete. The concrete for the specimens was placed and compacted by vibrating the mold in a cylindrical shape to minimize the existence of voids. After casting, the samples were covered with a plastic sheet to avoid loss of moisture and then left for cure under room conditions for 7 days. After the completion of the curing process, the prepared specimens were de-molded and taken up for thermal analyses (Figure 1a).

Table. 1 Summary of materials and method adopted in the current research

Parameter	**Details**
Research Objective	To investigate the compressive strength of coal slurry-based SCC under varying temperatures.
Sample Type	Normal concrete and coal slurry (CS) modified concrete (10%, 20%, 30% cement replacement).
Sample Dimensions	Cylinder: 0.15 m diameter × 0.30 m height.
Mix Design Ratio	Cement: Sand: Aggregate = 1:1.5:1.5.
Water-Cement Ratio (W/C)	0.40
Temperature Range	23°C, 300°C, 400°C, 600°C, 700°C, 800°C, 900°C.
Testing Duration	2 and 4 hours at each temperature in the furnace (microwave oven).
Replacement Levels of Cement	10%, 20%, and 30% replacement with coal slurry.
Testing Equipment	Universal Testing Machine (UTM).

2.3 Thermal Exposure

This experiment was performed in two stages and aims to investigate the performance of SCC in high-temperate conditions. During this first phase of the laboratory tests performed on concrete cylinders without the replacement of CS they had to be subjected to temperatures varied from 23°C up to 900°C in the controlled furnace atmosphere. In the second phase of the study, a similar temperature range was applied to the concrete cylinders with 10%, 20%, and 30% of CS replacement. Both specimens were heated for 2 hours and 4 subsequent hours to analyze the effect of prolonged heat exposure on residual compressive strength (Figure 1b).

2.4. Heating Procedure

The specimens were exposed to fire conditions by placing them in a furnace with an extreme but controlled temperature. The furnace temperature was raised slowly so that a condition known as thermal shock and spalling could not occur. The heating rate conformed to the conventional fire curve, able to achieve the setting temperature (for example 300°C, 400°C, 600°C, 700°C, 800°C, and 900°C) within the set time. Once the desired temperature was achieved, the specimens were held at that temperature for the required time 2 hours and 4 hours each. Finally, after the heating period, the furnace was switched off and the specimens to cooled in the furnace to room temperature for 24 hours (Figure 1b).

2.5. Compressive Strength Testing

The compressive strength of the specimens was determined after thermal exposure through a Universal Testing Machine (UTM) (Figure 1c-d). Cylinders were oriented in loading fixtures of the machine and an axial load was successively applied until failure. The maximum load sustained by the cylinder was recorded and used to calculate the compressive strength according to the standard formula:

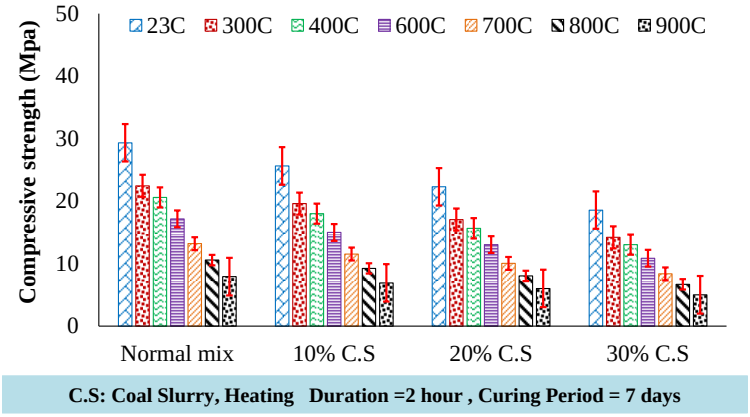
$$\mathrm{fc} = \frac{\mathrm{P}}{\mathrm{A}} \qquad (1)$$

where fc is the compressive strength of the sample (MPa), P is the maximum load (N), and A is the cross-sectional area of the cylinder in (m^2).

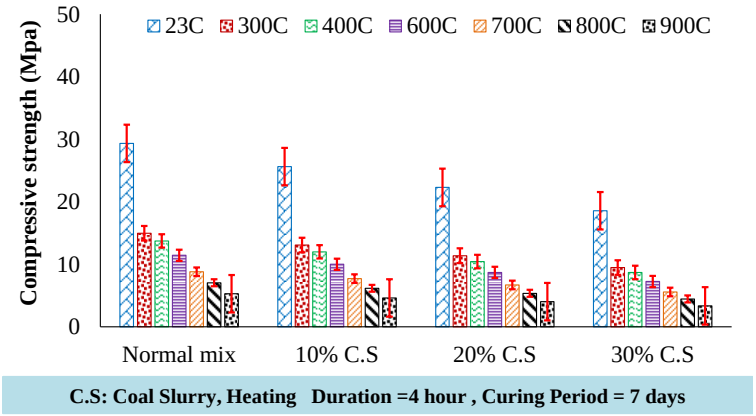
1. Results and Discussion

The findings shown in Figure 2 show the strength at different temperatures; 23°C-900°C of self-compacting concrete and normal concrete and cement with CS replacement of 10%, 20%, and 30%. From the results obtained, it is clear that the overall compressive strength decreased progressively with the increase in temperature indicating thermal degradation on SCC. At the 7-day curing stage, SCC demonstrates its early-age behaviour, the degree of reaction of the cement with water, and its ability to withstand heat as shown in Figure 2. Normal SCC shows a significantly higher strength retaining capacity as compared to the other conditions in all the conditions tested a 2 hour heating time at 23°C provides for 29.33 MPa. At 900°C the strength is 7.92 MPa now, which is half the strength of the base with 73% loss. The second best result is got from SCC with 10% CS which has an UTM of 25.63 MPa at 23°C and 6.92 MPa at 900°C, the % reduction being almost the same. 7-day strengths of mixes with 20% and 30% CS reduce from 22.29 MPa to 6.02 MPa and 18.56 MPa to 5.01 MPa, respectively at 900°C. Prolongation of heating periods aggravates these losses even more.

At temperatures above 600°C, the compressive strength declined steeper, as indicated in the range of 700–900°C due to the extreme microstructural changes such as aggregate crushing, as well as deterioration of cement paste. The normal mix of the test concrete subjected to heating at 900°C had only 70% of its initial strength of 29.33 MPa, while the 10%, 20% and 30% CS concrete mixes had 74.25% of 6.92 MPa, 6.02 MPa and 5.01 MPa, respectively. These changes revealed that CS-modified concrete strength was more sensitive to temperature variation than normal concrete mix at all the tested temperatures. For example, the reduction of the normal mix compressive strength at 900°C concerning its initial value was 74.25% for 10% of CS, 73.6% for 20% of CS, and 75.02% for 30% of CS. This trend confirms that the fall in thermal stability and quality of a coal slurry made partially as a replacement for cement is unfavorable. However, based on the percentage decrease in Figure 2 it showed that CS-modified SCC can perform as well as the normal mix at extreme temperatures if the level of replacement is controlled to 10%.



(a)



(b)

Figure 2. Compressive strength of 7 days normal and treated sample under various range of temperature and time (a) for 2-hour duration (b) for 4 hours duration.

2. Conclusion

In the present work, the effect of thermal exposure and the effect of the partial replacement of cement with coal slurry on the compressive strength of self-compacting concrete have been explored. The obtained results of the experiments revealed the tendency of a systematic reduction of the compressive strength with the rising temperature for both normal and CS-modified concrete. The normal mix had the highest compressive strength at room temperature (23°C), the 10%, 20%, and 30% CS mix followed the same order. All the samples, on the other hand, suffered severe loss of strength of between 74.25% and 75.02% when the temperature was raised from 23°C to 900°C in the normal mix, and the CS-modified mixes, respectively. The results suggest that thermal degradation at the microstructural level occurs due to dehydration of cement paste, desolventizing of calcium hydroxide and disintegration of aggregate becomes prominent at higher temperatures. Hence, the normal mix blend has somewhat higher compressive strength than the coal slurry

incorporated SCC mix blend, albeit at a 10% replacement for all the latter, the performance still effectively complements the desired outcome of concrete at high temperatures. The results also suggest that SCC can be made from coal slurry to be a viable solution for substituting cement and is broadly effective for applications that demand heat stability. This paper stated that there is a need to optimize the replacement percentage to meet the above mechanical requirements and integrated sustainability.

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Combined Effect of Water-Reducing Admixture and Recycled Fine Aggregate on the Workability of Concrete

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Abstract

Concrete workability is a crucial factor in ensuring the quality and durability of construction projects. This study investigates the effect of recycled fine aggregates (RFAs) and water-reducing admixtures (WRAs) on the slump value of concrete. The slump test was conducted to assess the workability of concrete mixes with varying levels of RFAs replacement (0%, 50%, 75%, and 100%). The results indicate that the incorporation of RFAs and WRAs improves the slump value compared to conventional concrete made with natural fine aggregates (NFAs). At 0% replacement, the slump increased from 85 mm (NFAs) to 95 mm (NFAs + WRAs). Further increments in RFAs replacement resulted in higher slump values, reaching a peak of 115 mm at 75% replacement before slightly decreasing to 110 mm at 100% replacement. These findings suggest that using RFAs with WRAs can enhance the workability of concrete, making it a viable alternative for sustainable construction practices.

Keywords: Slump Value, Workability, Recycled Fine Aggregates, Water-Reducing Admixtures, Concrete Mix Design.

1. Introduction

Concrete remains the most widely used construction material due to its strength, durability, and availability. However, the depletion of natural fine aggregates (NFAs) and environmental concerns have led to the exploration of sustainable alternatives. Recycled fine aggregates (RFAs), derived from demolished concrete waste, offer a viable solution but tend to affect workability due to their porous nature. To counteract this, water-reducing

admixtures (WRAs) can be used to improve slump while maintaining strength and durability. This study evaluates the effect of RFAs and WRAs on concrete workability through slump value measurements.

Several studies have explored the use of recycled aggregates in concrete. Neville (2011) emphasized the impact of aggregate quality on concrete performance, highlighting the need for admixtures to improve workability. Mehta and Monteiro (2014) demonstrated that recycled aggregates tend to have a higher water absorption rate, which can reduce workability unless compensated with WRAs. Recent studies (ASTM C143, 2015) indicate that the combination of RFAs and WRAs can enhance slump while maintaining structural integrity. However, the optimal replacement levels for RFAs remain a subject of research.

Previous studies have mainly focused on coarse recycled aggregates, with limited research on fine aggregates. Additionally, most research lacks a detailed assessment of the combined effects of RFAs and WRAs on workability. There is a need to determine the optimal RFAs replacement level that maximizes workability without compromising other properties of concrete.

2. Objective of the Study

- To evaluate the effect of different RFA replacement levels on the slump value of concrete.
- To determine the effectiveness of WRAs in enhancing workability when using RFAs.
- To identify the optimal RFA replacement percentage that balances workability and sustainability.

3. Materials Properties

3.1. Cement (Binder)

The primary binding agent in concrete is Ordinary Portland Cement (OPC), specifically Kohat Cement (43 grade), which complies with ASTM or IS standards. According to ASTM guidelines, the fineness of cement is assessed using ASTM C204 (Standard Test Methods for Fineness of Hydraulic Cement by Air Permeability Apparatus) or ASTM C430. The specific gravity of the cement, recorded as 3.14, is determined following ASTM C188 (Standard Test Method for Density of Hydraulic Cement). Since cement undergoes a chemical reaction with water rather than absorbing it, its water absorption is labelled as "Not Applicable (NA)", as per ASTM C150 (Standard Specification for Portland Cement). The bulk density of the cement, measured at 1440 kg/m^3, is also determined according to ASTM C188, which provides guidelines for evaluating the density of hydraulic cement for mix proportioning and storage. Adhering to these ASTM standards ensures consistency in

cement characteristics, supporting quality control in concrete manufacturing. Shown in Table 1.

3.2. Fine Aggregate (FA) - Sand

Fine aggregate, primarily consisting of natural river sand and recycled materials from demolished plaster and concrete, is an essential component in concrete mixtures. Particles passing through a 4.75mm sieve are classified as fine aggregates. The sand used follows ASTM standards and exhibits key properties that influence concrete performance. According to ASTM C136, the fineness modulus is 2.60, signifying a well-graded particle size distribution that enhances workability. The specific gravity, determined using ASTM C128, is 2.67, representing its relative density compared to water, which plays a role in mix proportions. Water absorption, tested in accordance with ASTM C128, is 2.00%, indicating minimal moisture retention that affects the water-cement ratio. The bulk density, measured as per ASTM C29/C29M, is 1584 kg/m^3, reflecting its mass per unit volume an important factor in mix design. Compliance with ASTM standards ensures the consistency and quality of sand in concrete applications. Shown in **Table 1.**

3.3. Recycled Fine Aggregates (RFAs)

Recycled fine aggregates (RFAs) are obtained from crushed plaster and concrete waste, which is then sieved through a 4.5mm mesh. The characteristics of RFAs are assessed using ASTM testing methodologies. As per ASTM C136, their fineness modulus is 2.80, indicating a particle distribution closer to that of cement. The specific gravity, tested according to ASTM C128, is 2.52, which is lower than that of natural sand, affecting proportioning in concrete mixtures. Water absorption, measured under ASTM C128, is 3.97%, significantly higher than natural sand due to the porous structure of RFAs, necessitating adjustments in the water-cement ratio. Additionally, the bulk density, determined following ASTM C29/C29M, is 1358 kg/m^3, lower than natural sand, influencing concrete density and mix proportions. These characteristics highlight the need for tailored mix designs when integrating RFAs into concrete production. Shown in **Table 1.**

3.4. Coarse Aggregate (CA)

Coarse aggregates, consisting of crushed stone particles that pass through a 19mm sieve but are retained on a 4.75mm sieve, provide strength and bulk to concrete mixtures. Their properties, tested according to ASTM standards, ensure structural stability and performance. The fineness modulus, assessed as per ASTM C136, is 2.60, indicating appropriate gradation for effective load-bearing capacity. The specific gravity, measured under ASTM C127, is 2.65, signifying a higher density than sand but lower than cement. Water absorption, evaluated according to ASTM C127, is 1.00%, indicating lower moisture

retention compared to RFAs but slightly higher than cement, which influences the mix design. The bulk density, determined using ASTM C29/C29M, is 1650 kg/m³—the highest among the aggregate materials—significantly contributing to the concrete's weight and structural integrity. These properties emphasize the role of coarse aggregates in enhancing the strength and durability of concrete structures. Shown in **Table 1.**

Table 1: Show the Properties of Cement, FA, RFAs and CA.

Properties	Binder - Cement	FA - Sand	FA - RFAs	CA
Fineness Modulus	2.80	2.60	2.80	2.60
Specific Gravity	3.14	2.67	2.52	2.65
Water Absorption	NA	2.00	3.97	1.00
Bulk Density kg/m³	1440	1584	1358	1650

3.5. Water Potable water free from impurities. Water plays a crucial role in various industrial and construction applications, and its properties are evaluated using specific ASTM standards. The **density** of water, measured as per **ASTM D1475,** is 1.01 g/cm³, which falls within the acceptable range of 1.0-1.02 g/cm³, ensuring consistency in composition. The **solid content**, tested according to **ASTM D2939,** is 43%, indicating the presence of dissolved or suspended solids within the acceptable range of 40%-50%. The **pH value**, determined using **ASTM E70,** is 8.0, classifying the water as slightly alkaline, which is within the standard range of 7-10. These properties influence water's suitability for applications such as concrete mixing, coatings, and industrial processes, Shown in Table 2.

Table 2: Show the Properties of Water.

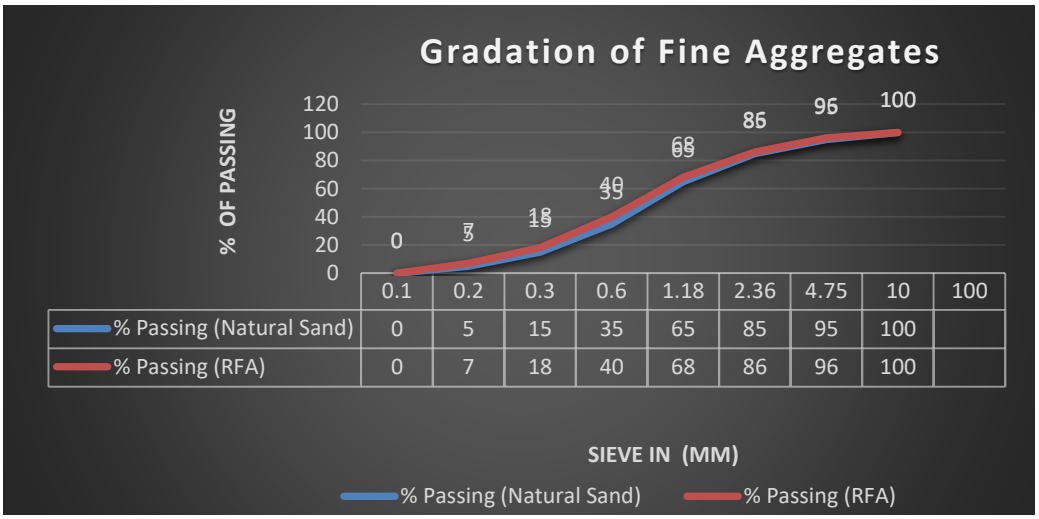
Test	Value	Range (IS)	ASTM Standard	ASTM Range
Density	1.01 g/cm³	1.0-1.02 g/cm³	ASTM D1475	1.0-1.2 g/cm³
Solid Content	43%	40%-50%	ASTM D2939	40%-50%
PH Value	8.0	8-10	ASTM E70	7-10

Property	Test Method	Value
Component	-	Single
Form	-	Liquid
Colour	-	Dark Brown
Specific Gravity	ASTM C 494	1.16 +/- 0.02
Air Entrainment	ASTM C 231	Up to 2% Over Control Max

Chloride Content	BSEN 480-10	Nil to BSEN 934-2
pH	ASTM C 494	7-9

3.6. Water-Reducing Admixture (WRAs): High-range water-reducing admixtures (superplasticizers) to improve workability without increasing water content. i.e. Max Flo P, Shown in **Table 3.** **Table 3: Show the Properties of WRAs.**

3.7.



Grading of Aggregates: The grading of aggregate is a crucial factor to consider when replacing any material. In this study, the grading of recycled fine aggregate (RFA) was evaluated against natural sand. The results indicated that RFA exhibited characteristics similar to those of conventional aggregates, demonstrating comparable performance. This similarity in grading suggests that RFA can be a viable alternative to natural sand in construction applications, as shown in Fig. 1.

Fig. 1. Gradation of Fine Aggregates

3.8. Mix Design Proportion (Grade M15 = 1:2:4)

Concrete was designed with a constant water-cement ratio while varying the proportion of RFAs as replacements for NFAs at 0%, 50%, 75%, and 100%. The WRA dosage was maintained at 4% across all RFA-replaced mixes. Concrete mix design is a crucial process that determines the appropriate proportions of cement, fine aggregate, coarse aggregate, water, and admixtures to achieve the **desired workability and strength of concrete.** The concrete mix consists of different compositions based on the materials used and the water-cement (W/C) ratio. The first mix, labelled as **Normal Concrete**, includes cement, sand, and aggregate in a proportion of 1:2:4 with a W/C ratio of 0.7, without any water-reducing admixtures (WRAs). The second mix, **Normal Concrete with WRAs**, maintains the same material proportions (1:2:4) but reduces the W/C ratio to 0.5 while incorporating 4% WRAs to enhance workability and performance. The third mix, **RFA with WRAs Concrete**, also follows the 1:2:4 proportion, with a W/C ratio of 0.5 and 4% WRAs, but replaces natural fine aggregate with recycled fine aggregate (RFA), making it a more sustainable alternative. These variations allow for the optimization of strength, durability, and sustainability in concrete applications. Shown in **Table 4.**

Table 4: Show Mix Design Proportion.

Concrete	Cement	Fine Aggregate	Coarse Aggregate	W/C Ratio	WRAs
Normal Concrete	1	2	4	0.7	0%
Normal Concrete, WRAs	1	2	4	0.5	4%
RFAs Concrete, WRAs	1	2	4	0.5	4%

3.9. Effect of WRAs on Workability of NFAs

The graph illustrates the impact of water-reducing admixtures (WRAs) on the workability of concrete containing natural fine aggregates (NFAs). The slump value, which indicates

concrete workability, is plotted on the y-axis, while the x-axis represents the proportion of natural fine aggregate used. The blue bar represents NFAs without WRAs, showing a slump value of 85 mm. In contrast, the orange bar represents NFAs mixed with 4% WRAs, resulting in an increased slump value of 95 mm. This indicates that the addition of WRAs significantly enhances the workability of concrete, making it more fluid and easier to handle. The increased slump value suggests that WRAs improve the flowability of the concrete mix, reducing the water demand while maintaining the desired consistency and strength. Shown in Fig. 2.

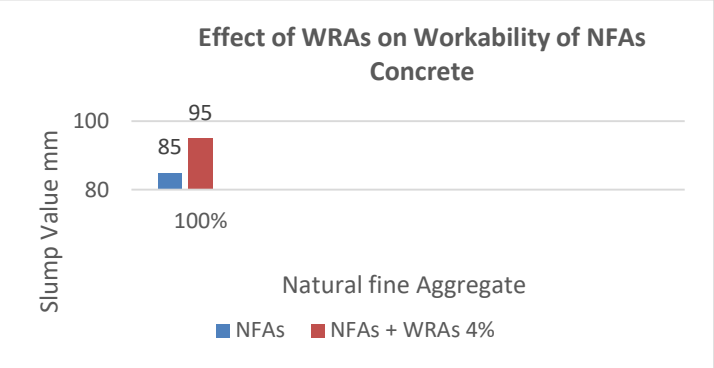


Fig. 2. **Effect of WRAs on Workability of NFAs Concrete**

4. Casting of Specimen

The specimen mixing process involved different combinations of natural fine aggregates (sand) and recycled fine aggregates (RFA) with and without water-reducing admixtures (WRAs). The first combination consisted of 100% sand with 0% RFA and no WRAs, resulting in three slump test samples. The second combination maintained 100% sand but incorporated 4% WRAs, also producing three slump test samples. In the third combination, the mix included 50% RFA and 50% sand with 4% WRAs, yielding three slump test samples. The fourth combination increased the RFA content to 75% while reducing sand to 25%, along with 4% WRAs, again resulting in three slump test samples. Finally, the last combination consisted entirely of 100% RFA with 4% WRAs and no natural sand, maintaining the trend of three slump test samples. These variations were designed to assess the impact of different RFA proportions and the presence of WRAs on the workability of concrete. Shown in **Table 5.**

Table 5: Show Casting of Specimen.

Specimen Mixing	Combinations	Workability Slump Test Samples (mm)
Normal Concrete	Sand 100% + RFA 0% + WRAS 0%	3
Normal Concrete, WRAs	Sand 100% + RFA 0% + WRAS 4%	3
RFA Concrete, WRAs	RFA 50% + Sand 50% + WRAs 4%	3
RFA Concrete, WRAs	RFA 75% + Sand 25% + WRAs 4%	3
RFA Concrete, WRAs	RFA 100% + Sand 0% + WRAs 4%	3

5. Workability (Slump Value Test)

The slump test was performed according to ASTM C143 to evaluate the workability of different mixes. The workability of different concrete mixtures was evaluated through slump tests. The Normal concrete mix, consisting of 100% sand with no recycled fine aggregate (RFA) or water-reducing admixtures (WRAs), exhibited a slump of 85 mm. When 4% WRAs were added to the same mix, the slump increased to 95 mm, indicating improved workability. Further modifications involved replacing sand with RFA while maintaining a 4% WRAs content. A mix with 50% RFA and 50% sand resulted in a slump of 105 mm, while increasing the RFA content to 75% led to a slump of 115 mm. However, when sand was completely replaced with 100% RFA, the slump slightly decreased to 110 mm. These results suggest that increasing RFA content generally enhances workability, though excessive replacement may reduce the effect.

Table 6: Show Workability of Specimen.

Specimen Mixing	Combinations	Samples	Workability Slump Test (mm)
Normal Concrete	Sand 100% + RFA 0% + WRAS 0%	3	85
Normal Concrete, WRAs	Sand 100% + RFA 0% + WRAS 4%	3	95
RFA Concrete, WRAs	RFA 50% + Sand 50% + WRAs 4%	3	105
RFA Concrete, WRAs	RFA 75% + Sand 25% + WRAs 4%	3	115
RFA Concrete, WRAs	RFA 100% + Sand 0% + WRAs 4%	3	110

The slump height was measured and recorded. The graph titled **"Slump Value Graph"** illustrates the relationship between **RFAs replacement** percentages and the corresponding **slump values (in mm)**. The **x-axis** represents the percentage of **RFAs replacement**, ranging from **0% to 100%**, while the **y-axis** represents the **slump value (in mm)**, ranging from **0 to 150 mm**. Two categories of data are displayed: **NFAs (Normal Fine Aggregates)** in **blue** and **RFAs + WRAs 4% (Recycled Fine Aggregates with Water-Reducing Admixtures at 4%)** in **orange**. At **0% replacement**, the slump value for **NFAs** is **85 mm**, whereas for **RFAs + WRAs 4%**, it is slightly higher at **95 mm**. As the **RFA replacement percentage increases**, the slump values continue to rise, reaching a peak of **115 mm at 75% replacement**. However, at **100% replacement**, the slump value slightly decreases to **110 mm**. This trend suggests that incorporating **RFAs with WRAs at 4%** enhances workability initially, but at full replacement, the slump value slightly declines. Shown in **Fig. 3.**

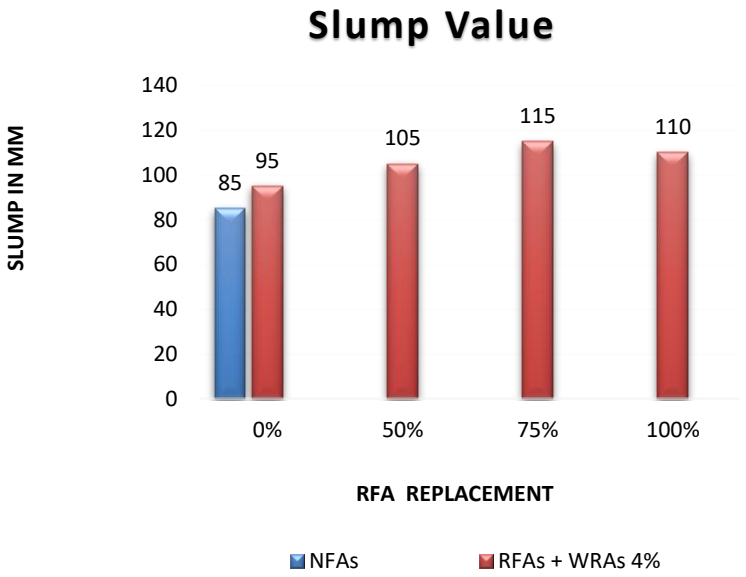


Fig. 3. Show the workability against different proportion of RFAs

6. Results and Discussion: The results of the slump test reveal a noticeable increase in slump value with the inclusion of RFAs and WRAs, indicating improved workability. At 0% replacement, the slump increased from 85 mm for NFA concrete to 95 mm when RFAs and WRAs were introduced, demonstrating a significant enhancement. As the replacement level increased to 50%, the slump value further rose to 105 mm, maintaining a positive trend. The highest slump value of 115 mm was observed at 75% replacement, suggesting that this level provided the optimal improvement in workability. However, at 100% replacement, the slump slightly decreased to 110 mm, which could be attributed to the increased water absorption capacity of RFAs, necessitating further optimization. This trend suggests that while RFAs contribute to better workability, excessive replacement may reduce effectiveness due to higher water demand. The combined effect of RFAs and WRAs offers a promising approach for achieving sustainable and highly workable concrete

7. Conclusion

Workability Enhancement: Incorporating Recycled Fine Aggregates (RFAs) with Water-Reducing Admixtures (WRAs) significantly improves the workability of concrete. This improvement is evident in the increased slump values, which measure the concrete's consistency and ease of placement.

The study identifies that an RFA replacement level of approximately 75% provides the best workability results. At this level, the slump values are maximized, indicating a highly

workable concrete mix. However, when the RFA content exceeds 75%, a slight decline in the slump is observed, suggesting a potential limitation in further increasing RFA content.

The results demonstrate that RFAs, when combined with WRAs, can effectively replace Natural Fine Aggregates (NFAs) without significantly reducing workability. This suggests that RFAs, in conjunction with WRAs, present a sustainable and eco-friendly alternative to traditional NFAs. Further studies should investigate the effects of RFAs on concrete strength, durability, and long-term performance. This research would help determine the structural reliability and practical applicability of RFAs in various construction scenarios.

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Workability and Material Testing of SBR and Polypropylene Rope Reinforced Concrete with Mixed Aggregates

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Abstract

This study investigates the workability characteristics of polymer fiber-reinforced M20-grade concrete and the material properties of its key constituents, including cement, sand, brick aggregate, natural aggregate, styrene- butadiene rubber (SBR), polypropylene rope fiber, and water. Standardized material tests were conducted to assess the quality and suitability of each component. Cement was tested for fineness, consistency, initial and final setting time, and specific gravity. Fine and coarse aggregates, including both natural and brick aggregates, were evaluated for gradation, water absorption, bulk density, and specific gravity. The influence of SBR polymer and polypropylene rope fiber on concrete workability was studied using the slump test, considering their effects on cohesion and flow ability. Results indicated that increasing fiber content reduced workability due to higher cohesion, while the inclusion of SBR improved mix stability. Brick aggregates exhibited higher water absorption, influencing the water-cement ratio and overall mix behavior. This study provides insights into optimizing mix proportions for improved workability in polymer fiber-reinforced concrete with hybrid aggregates.

Keywords: Cement, Sand, Brick Aggregate, Natural Aggregate, Styrene Butadiene Rubber, Polypropylene Rope Fiber, Workability, Slump Test, Water Absorption, Specific Gravity.

1. Introduction

Concrete is the base of construction materials due to its strength, durability, and versatility. However, optimizing workability while maintaining desirable mechanical and durability properties remains a challenge, especially when incorporating alternative aggregates and additives [1], [2]. The inclusion of polymer and fiber in concrete has gained significant attention for enhancing its performance characteristics. Styrene-butadiene rubber (SBR) polymer is known to improve adhesion, flexibility, and resistance to water penetration, while polypropylene rope fiber enhances toughness and crack

resistance [3],[4].This study investigates the workability of M20-grade polymer fiber-reinforced concrete using both natural and brick aggregates. Due to its high water absorption capacity, brick aggregate affects the water-cement ratio, influencing the overall mix behavior [5,6]. Standardized material tests were conducted to assess the key constituents, including cement, fine and coarse aggregates, SBR polymer, polypropylene rope fiber, and water. Workability was evaluated using the slump test, which measures the effects of polymer and fiber on cohesion and flow ability [7], [8].The results indicate that increasing fiber content reduces workability due to enhanced cohesion, while the addition of SBR polymer improves mix stability. Understanding the interaction between these components provides valuable insights into optimizing mix proportions, ensuring a balance between workability and mechanical performance [9], [10]. This research contributes to the development of polymer fiber-reinforced concrete with hybrid aggregates, offering potential benefits for sustainable and high-performance construction applications.

1. Materials and Methodology

2.

2.1 Materials

The materials utilized in this study include **Ordinary Portland Cement (OPC) 43 grade**, **fine aggregate**, **coarse aggregate**, **coarse brick aggregate**, **Styrene-Butadiene Rubber (SBR)**, and **Polypropylene Rope Fiber**, all conforming to ASTM standards.

2.2 Mix Design Proportion

Styrene Butadiene Rubber (SBR) polymer (10%) and **Polypropylene (PP) rope fiber (0–1%)** are incorporated into M20 grade concrete. The mix variations focus on different aggregate compositions while following ASTM standard guidelines as shown in Table 1.The **control mix** consists of **100% natural aggregates** with a proportion of **1:1.65:3.08 (Cement: Fine Aggregate: Coarse Aggregate)** and a **water- cement ratio of 0.50**, making it suitable for conventional construction. The second variation introduces **10% SBR polymer and 0–1% PP rope fiber**. To evaluate the effect of **brick aggregates**, the third mix replaces **50% of the natural aggregate with brick aggregate**, while cement and fine aggregate proportions remain unchanged. Due to the **higher absorption capacity of brick aggregate**, the **water-cement ratio is increased to 0.56** to ensure proper hydration and strength development. The final mix completely replaces **natural aggregate with 100% brick aggregate**, requiring an **even higher water-cement ratio of 0.60** to maintain hydration and strength.

Table.1 Mix Design Proportion for Different Compositions

Mix Type	Cement	Fine Aggregate	Coarse Aggregate	Water	Polymer (SBR)	Fiber (PP Rope)
100% Natural Aggregate	1	1.65	3.08	0.50	0%	0%
100% Natural Aggregate (With Polymer & Fiber)	1	1.65	3.08	0.50	10%	0–1%
50% Natural + 50% Brick Aggregate (With Polymer &	1	1.65	3.08	0.56	10%	0–1%

Fiber)						
100% Brick Aggregate (With Polymer & Fiber)	1	1.63	3.08	0.60	10%	0–1%

2.3 Workability Analysis (Slump Test): Workability refers to the ease with which concrete can be mixed, placed, compacted, and finished without segregation or excessive bleeding. The workability of the different mix types in this study is influenced by the composition of natural and brick aggregates, the presence of styrene-butadiene rubber (SBR) polymer, and the percentage of polypropylene (PP) rope fiber.

1. Results and Discussion

1.1 CEMENT

OPC 43 grade cement was used, with a specific gravity of **3.12** (ASTM C188), ensuring appropriate density. The fineness was **5%** (ASTM C430), indicating adequate particle size distribution. Standard consistency was **27%** (ASTM C187), ensuring optimal water demand. Initial and final setting times were **128 minutes** and **317 minutes**, respectively, meeting ASTM C191 requirements.

Table.2 Cement Test Results for OPC 43 Grade Standard (ASTM C150)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Specific Gravity	ASTM C188	3.12	3.10 - 3.15
Fineness %	ASTM C430	5%	≤ 10%
Standard Consistency	ASTM C187	27%	26 - 33%
Initial Setting Time	ASTM C191	128 minutes	≥ 45 minutes
Final Setting Time	ASTM C191	317 minutes	≤ 375 minutes

1.2 COARSE AGGREGATE (Natural)

The specific gravity of coarse aggregate was 2.66 (ASTM C127), with a water absorption rate of 1.02% (ASTM C127), indicating low porosity. The flakiness and elongation indices were 16% and 26%, respectively (ASTM D4791), confirming good particle shape. The impact, crushing, and abrasion values were 9.1%, 19.50%, and 21.26% (ASTM D5874, ASTM C131), ensuring adequate toughness and strength.

Table.3 Coarse Natural Aggregate Test Results Standard (ASTM C33)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Specific Gravity	ASTM C127	2.66	2.6 - 2.9
Water Absorption (%)	ASTM C127	1.02%	≤ 2%

Flakiness Index (%)	ASTM D4791	16%	≤ 25%
Elongation Index (%)	ASTM D4791	26%	≤ 35%
Aggregate Impact Value (%)	ASTM D5874	9.1%	≤ 20%
Aggregate Crushing Value (%)	ASTM C131	19.50%	≤ 25%
Aggregate Abrasion Value (%)	ASTM C131	21.26%	≤ 30%

1.3 FINE AGGREGATE (Sand)

Fine aggregate exhibited a specific gravity of **2.66** (ASTM C128) and a fineness modulus of **2.74** (ASTM C136), confirming well-graded particle distribution. Water absorption was measured at **1.4%** (ASTM C128), ensuring minimal porosity and better durability.

Table.4 Fine Aggregate Test Results Standard (ASTM C33)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Specific Gravity	ASTM C128	2.66	2.6 - 2.9
Fineness Modulus (FM)	ASTM C136	2.74	2.0 - 3.0
Water Absorption (%)	ASTM C128	1.4%	≤ 3%

1.1 COARSE AGGREGATE (Brick)

Brick aggregate had a specific gravity of **2.25** (ASTM C127) and a water absorption rate of **9.5%**, indicating higher porosity. Flakiness and elongation indices were **20%** and **18%** (ASTM D4791), while impact, crushing, and abrasion values were **6.8%**, **23.5%**, and **33.3%** (ASTM D5874, ASTM C131), demonstrating satisfactory strength characteristics.

Table.5 Coarse Brick Aggregate Test Results Standard (ASTM C33)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Specific Gravity	ASTM C127	2.25	2.2 - 2.5
Water Absorption (%)	ASTM C127	9.5%	≤ 20%
Flakiness Index (%)	ASTM D4791	20%	≤ 25%

Elongation Index (%)	ASTM D4791	18%	≤ 35%
Aggregate Impact Value (%)	ASTM D5874	6.8%	≤ 30%
Aggregate Crushing Value (%)	ASTM C131	23.5%	≤ 30%
Aggregate Abrasion Value (%)	ASTM C131	33.3%	≤ 35%

1.2 STYRENE BUTADIENE RUBBER (SBR)

SBR polymer was used as an additive, with a solid content of **46%** (ASTM D1417) and a density of **1.01 g/cm³** (ASTM D1475). The pH level was **9.5** (ASTM E70), viscosity **250 cP** (ASTM D2196), and bond strength **3.8 MPa** (ASTM C882), indicating good adhesion properties.

Table.6 Physical and Chemical Properties of SBR Polymer Standard (ASTM C1059)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Appearance	Visual Inspection	Milky white liquid	Milky white to light yellow
Solid Content (%) by Gravimetric Method	ASTM D1417	46%	45 - 55%
pH Level	ASTM E70	9.5	7 - 11
Density (g/cm³)	ASTM D1475	1.01	1.00 - 1.02
Viscosity (cP at 25°C)	ASTM D2196	250 cP	200 - 300 cP
Bond Strength (MPa)	ASTM C882	3.8 MPa	≥ 3 MPa

1.1 POLYPROPYLENE FIBER (Ropes)

Polypropylene rope fiber exhibited a tensile strength of **440 MPa** (ASTM D2256) and a density of **0.90 g/cm³** (ASTM D792). Water absorption was negligible (**0.01%**, ASTM D570). The fiber length and diameter were **38.1 mm** and **0.5 mm**, respectively, ensuring effective reinforcement in concrete.

Table.7 Physical and Mechanical Properties of Polypropylene Rope Fiber Standard (ASTM C1116)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Tensile Strength (MPa)	ASTM D2256	440MPa	350 – 800 MPa

Density (g/cm³)	ASTM D792	0.90 g/cm3	0.89 –0.93 g/cm3
Water Absorption (% by weight)	ASTM D570	0.01%	≤ 0.1%
Fiber Length (mm)	No Specific ASTM	38.1mm	30 – 40 mm
Fiber Diameter (mm)	No Specific ASTM	0.5mm	0.4 – 0.6 mm

1.2 WATER

Water quality plays a crucial role in determining the **workability, strength, and durability** of concrete. ASTM C1602 sets specific limits to ensure that mixing water does not adversely affect concrete performance. The pH level of **7.1** falls within the recommended range of **6.0 - 8.5**, allowing for proper cement hydration. The total dissolved solids (TDS) content is **1240 mg/L**, which is well below the **2000 mg/L** limit, indicating minimal impurities. Additionally, the chloride concentration of **460 mg/L** remains within the **500 mg/L** threshold for reinforced concrete, reducing the risk of corrosion. Based on these parameters, the water available in **Rahim Yar Khan meets ASTM C1602 standards**, making it **suitable for concrete mixing** while ensuring long-term structural durability.

Table.8 Water Test Results Standard (ASTM C1602)

Test Parameter	Obtained Value	Typical Range
Chloride Content mg/L	460	<500
Total Dissolved Solids (TDS) mg/L	1240	≤ 2000
pH Level	7.1	6.0- 8.5

Figure 1. Material Tests

2.4 Workability Results (Slump Test – ASTM C143)

Table.9 Slump for M20 Grade Concrete (Without Fibers & SBR) Using 100% Natural Aggregate

Mix Type	Slump Value (mm)	Workability Classification	Slump Range (mm)
M20 (Without Fibers & SBR)	81 mm	Medium Workability	50-100 mm

The slump test measures the workability and consistency of fresh concrete. For M20 grade concrete without fibers and SBR polymer, using 100% natural aggregate, the slump value was recorded as 81 mm. According to workability classifications, a slump value between 50 mm and 100 mm falls under the category of medium workability. This indicates that the concrete has a balanced consistency, making it suitable for manual placement, moderate reinforcement, and general construction applications. The mix retains good cohesion without excessive water content, ensuring adequate strength development and durability.

Table.10 Slump for M20 Grade Concrete (With Fibers & SBR) Using 100% Natural Aggregate

Mix Type (with additives)	Slump Value (mm)	Workability Classification	Slump Range (mm)
M20 with 10% SBR & 0.25% Polypropylene Fiber (100% NA)	85 mm	Medium to High	80 – 90 mm

M20 with 10% SBR & 0.75% Polypropylene Fiber (100% NA)	79 mm	Medium	70 – 85 mm
M20 with 10% SBR & 1.0% Polypropylene Fiber (100% NA)	73 mm	Medium	65 – 80 mm

The slump test for M20 grade concrete with SBR and polypropylene fibers demonstrates how the addition of these materials affects workability. When 10% SBR and 0.25% polypropylene fiber were added, the concrete exhibited a slump of 85 mm, indicating medium to high workability, which ensures ease of placement and compaction. As the fiber content increased to 0.75%, the slump value decreased to 79 mm, still within the medium workability range, as the fibers slightly restricted the flow of the mix. Further increasing the fiber content to 1.0% resulted in a slump of 73 mm, maintaining medium workability, but with reduced fluidity due to fiber interlocking. While SBR enhances workability, the gradual slump reduction with increasing fiber content highlights the balancing effect between improved cohesion and slight stiffening of the mix.

Table.11 Slump for M20 Grade Concrete (With Fibers & SBR) Using 50%Natural and 50% Brick Aggregate

Mix Type (with additives)	Slump Value (mm)	Workability Classification	Slump Range (mm)
M20 with 10% SBR & 0.25% Polypropylene Fiber (50% Brick + 50% Natural Aggregates)	86 mm	Medium	85 – 95 mm
M20 with 10% SBR & 0.75% Polypropylene Fiber (50% Brick + 50% Natural Aggregates)	82 mm	Medium	80 – 90 mm
M20 with 10% SBR & 1.0% Polypropylene Fiber (50% Brick + 50% Natural Aggregates)	76 mm	Medium	75 – 85 mm

The slump test for M20 grade concrete with 50% brick and 50% natural aggregates, incorporating 10% SBR and varying polypropylene fiber content, indicates a gradual reduction in workability as fiber content increases. With 0.25% fiber, the slump measured 86 mm, placing it in the medium workability range (85–95 mm), and ensuring ease of placement. As fiber content increased to 0.75%, the slump decreased to 82 mm, still within the medium range (80–90 mm), showing a slight reduction in fluidity due to fiber interlocking. At 1.0% fiber content, the slump further dropped to 76 mm, remaining in the medium category (75–85 mm), but with increased stiffness. The results highlight that while SBR improves workability, the higher water absorption of brick aggregates and increased fiber content contribute to a reduction in slump, affecting the overall consistency of the mix.

Table.12 Slump for M20 Grade Concrete (With Fibers & SBR) Using 100% Brick Aggregate

Mix Type (with additives)	Slump Value (mm)	Workability Classification	Slump Range (mm)
M20 with 10% SBR & 0.25% Polypropylene Fiber (100% Brick Aggregate)	89 mm	Medium–High	85–95 mm
M20 with 10% SBR & 0.75% Polypropylene Fiber (100% Brick Aggregate)	84 mm	Medium	80–90 mm
M20 with 10% SBR & 1.0% Polypropylene Fiber (100% Brick Aggregate)	78 mm	Medium	75–85 mm

The slump test for M20 grade concrete with 100% brick aggregate, incorporating 10% SBR and varying polypropylene fiber content, shows a progressive decrease in workability as fiber content increases. With 0.25% fiber, the slump was 89 mm, placing it in the medium–high workability range (85–95 mm), ensuring good flow and ease of placement. At 0.75% fiber content, the slump decreased to 84 mm, moving to the medium workability range (80–90 mm), indicating a slight reduction in fluidity due to fiber dispersion. With 1.0% fiber, the slump further dropped to 78 mm, still classified as medium workability (75–85 mm), but with increased stiffness and reduced flow. These results suggest that SBR enhances workability, but the higher water absorption of brick aggregates and fiber interlocking effects contribute to a decrease in slump, making the mix stiffer as fiber content increases.

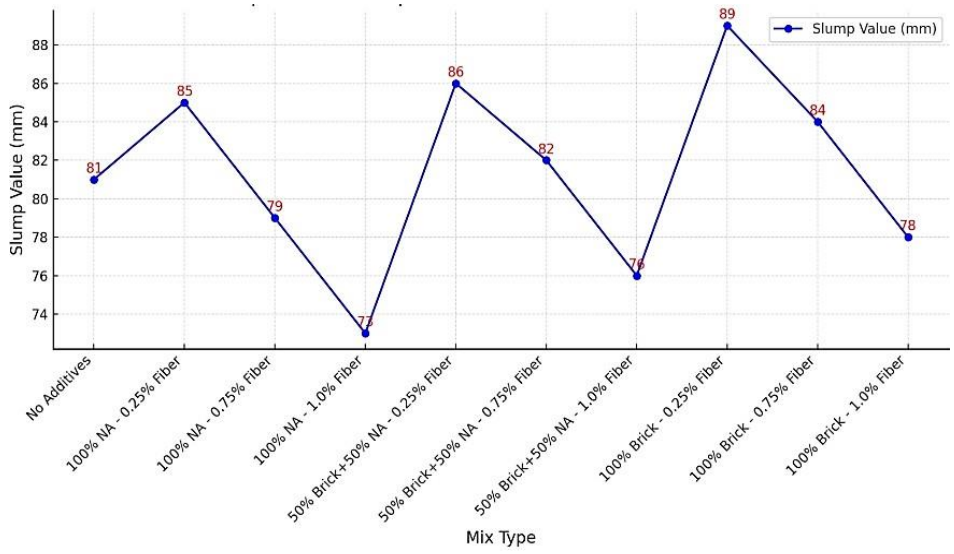

Figure.2 Comparison of Slump Values for Different M20 Concrete Mixes

Figure.3 Slump Test

3. Conclusion

This research investigated the workability of M20 grade concrete with various aggregate compositions, incorporating SBR polymer and polypropylene fibers to enhance properties. The study focused on six different mix variations, with natural aggregate (NA) and brick aggregate (BA) used in different proportions while maintaining a fixed 10% SBR polymer and varying polypropylene fiber percentages (0% to 1%). The results provide insights into the effectiveness of alternative aggregates in improving concrete properties.

3.1 Workability Analysis (Slump Test)

The control mix (100% NA, without polymer and fiber) exhibited a slump of 81 mm, classifying it as medium workability (50-100 mm range). Incorporating SBR polymer and fibers generally improved workability compared to the control mix due to SBR's plasticizing effect, but higher fiber content slightly reduced workability. Mixes containing brick aggregates showed higher slump values initially due to their porous nature, but water absorption led to slightly reduced workability at higher fiber contents. The 100% BA mix with SBR and fibers exhibited the highest slump (89 mm with 0.25% fiber), making it more workable compared

to other modified mixes.

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ANALYZING THE EFFECT OF FLY ASH AND INDUS RIVER SAND ON NON-AUTOCLAVED AERATED CONCRETE

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ABSTRACT: Concrete is considered the most widely used material in the construction industry, with an annual production rate of about 4.4 billion tons. As the demand for concrete continues to rise globally, the need for both cement and aggregates is increasing rapidly. The production of cement and extraction of aggregates on a large scale could have negative effects on the environment. This study focuses on developing sustainable non-autoclaved aerated concrete by partially replacing cement and fine aggregates with fly ash and Indus River sand, respectively. Fine aggregate is replaced with Indus River sand at different percentages (0 %, 10 %, 15 %,20 % and 25 %), while fly ash replaces 20% of the cement. After analyzing the results, it is found that by replacing Indus River Sand and fly ash, both the compressive strength and dry density increase, but water absorption decreases. The maximum value of compressive strength is obtained as 5.867 MPa by 20% replacement of Indus River sand, and the maximum value of dry density is obtained as 1204.5 Kg/m3 by 25% replacement of Indus River at 28 days curing, while the value of water absorption decreases, and minimum value of water absorption is obtained as 19.647% by 25% replacement of Indus River sand at 28 days curing. This study contributes to overall well-being by providing a sustainable method for producing non-autoclaved aerated concrete while preserving natural resources, particularly natural aggregates and this study provides light weight material that could help in reducing the dead load of structures.

KEYWORDS: Fly Ash, Indus River Sand, Light Weight, Non-Autoclaved Aerated Concrete, Sustainable Material

1. Introduction

Concrete is considered one of the most widely utilized material in the construction industry. It is prepared by mixing cement, fine aggregate, coarse aggregate and water. Among these materials, cement is the main ingredient to make concrete as it binds all components together. Cement production reached 4.4 billion tons a year in 2021 globally [1]. However, this large-scale production of cement comes with significant environmental challenges, as it is responsible for CO_2 emissions both during the production stage and throughout its lifecycle [2]. The cement industry alone is now

responsible for about 8% of global CO_2 emissions, these high emissions are due to the chemical and thermal processes involved in the cement production stage [3]. Therefore, the cement and concrete industry needs improvements to mitigate its effects on the environment. Beyond cement, the construction industry extensively utilizes sand, gravel and aggregates. These materials are the second most extensively used natural resource after water with an annual estimate of 40-50 billion metric tons. However, the natural formation of sand and gravel through erosive processes takes thousands of years, while their current extraction rate is far more than their renewal. This raises concerns about whether they will still be available in the future [4][5]. The Large-scale extraction of aggregates can have negative effects on the environment such as altered land use, blasting effect, noise, dust, displacement of communities and many more [6].

Excessive sedimentation is a problem for any river, including the Indus River. This excessive sedimentation can cause reduced flood capacity and many other issues. This sedimentation contains sand and gravel particles. It was found that excessive sedimentation accumulation has resulted in a 17.75% reduction in flood carrying capacity of Indus River Sand. Over the period of 24 years excessive sedimentation and low flows have caused a loss of 48.34% bank full discharge. It was emphasized in this study the need for sustainable sediment management strategies to address these effects [7].

Over the past decade, several studies have explored the effects of Indus River sand and fly ash on the properties of autoclaved aerated concrete (AAC), where Indus River Sand was utilized at various percentages 15%, 20%, 25%, and 30% respectively and fly ash was utilized as partial replacement with cement at 15%, 20%, and 25% respectively [8][9][10]. This study focuses on the development of sustainable and lightweight non-autoclaved aerated concrete by utilizing both Indus River Sand and Fly ash.

2. Materials and Methodology

2.1 Materials utilized in the preparation of non-autoclaved aerated concrete.

Following materials were used in the research process.

Table 1. Materials and their functions used in the mix design

Material	Source	Function
Cement	Lucky Cement Factory	Binder
Fly Ash	F Class	Binder
Indus River Sand	Indus River (Kotri Barrage)	Fine aggregate
Bholari Sand	Local Market Jamshoro	Fine aggregate
Lime	Saddar Hyderabad	Addition to Cement
Aluminum	Karachi	Aerating Agent
Water	Lab (Portable Water)	Hydration

2.1.1 Cement

Cement is a binder material, and it is used in the preparation of all types of concrete. Ordinary Portland cement (OPC) is used for non-autoclaved aerated concrete. The Ordinary Portland Cement utilized for this study follows the guidelines of ASTM C150.

2.1.2 Fly Ash

Fly ash is a byproduct that is generated during coal combustion. It is a pozzolanic material which has binding properties. In this study, it is used as a partial replacement for the cement. Fly ash has several advantages which include enhanced workability, improved durability, and potential to reduce overall construction costs.[11]

2.1.3 Lime

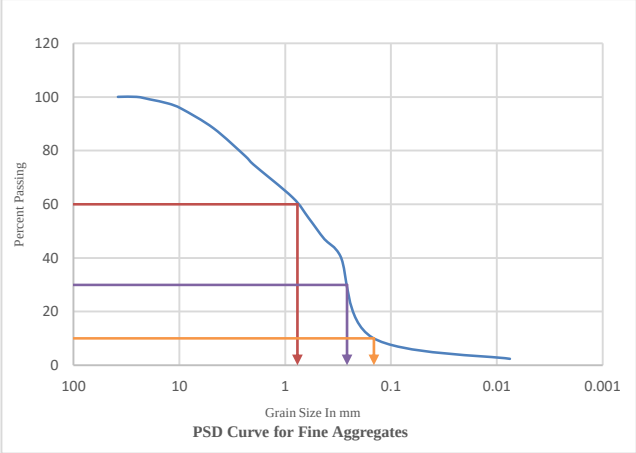
Lime is used in this study as an addition to cement. The addition of lime in non-autoclaved aerated concrete enhances its compressive strength [12]. Lime was obtained from the local market of Hyderabad. Lime utilized for this research was sieved through sieve #30.

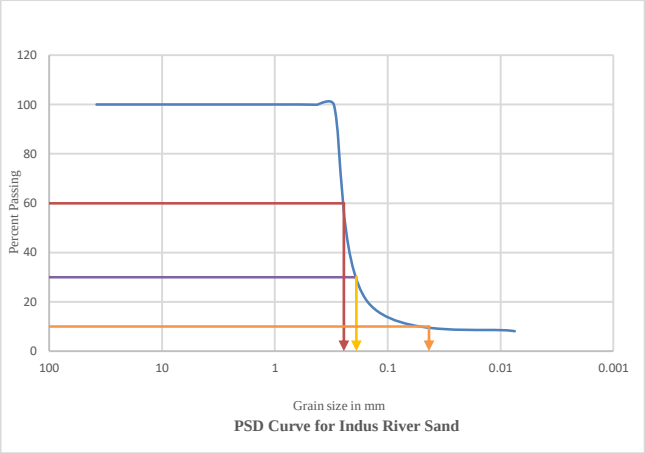
2.1.4 Fine Aggregates (Bholari Sand)

In this study, natural sand, also known as bholari sand was utilized. As per standard specifications for autoclaved aerated concrete ASTM C1693-11(reapproved 2017), quartz sand should be used for aerated concrete, which is also known as silica sand. For that, bholari sand was sieved. It was sieved through the #30 sieve (600 microns). To assess the quality of aggregates specific gravity and particle size distribution were determined. The specific gravity of the fine aggregates (bholari sand) was obtained by following standard specifications of ASTM D854. It was found that the specific gravity of the bholari sand was 2.67. Sieve analysis was conducted in by following specifications of ASTM C136, for determining the particle size distribution. From the graph the values of $D_{10,}$ $D_{30,}$ and D_{60} are obtained as 0.145 mm, 0.260 mm, and 0.768mm respectively. From these values, the coefficient of curvature (Cc) was calculated as 0.61 and the coefficient of uniformity (Cu) was calculated as 5.29, as Cu >5 and Cc lie between 0.5 and 2. Thus, it was found from the Particle size distribution curve that fine aggregates are well graded as shown in PSD curve below.

2.1.5 Indus River Sand

In this study, Indus River Sand was utilized as partial replacement for natural sand in non-autoclaved aerated concrete. Indus River Sand was extracted from the Indus River near Kotri Barrage, Jamshoro. To assess the quality of Indus River Sand specific gravity and particle size distribution were determined. To determine the specific gravity of the fine Indus River Sand, the standard specification of ASTM D854 was followed. It was found that the specific gravity of the Indus River Sand was 2.76. For determining the particle size distribution, sieve analysis was conducted by following specifications ASTM C136. From the graph the values of $D_{10,}$ $D_{30,}$ and D_{60} are obtained as 0.0043 mm, 0.190 mm, and 0.245 mm respectively. From these values, the coefficient of curvature (Cc) was calculated as 3.43 and the coefficient of uniformity (Cu) was calculated as 5.7, If Cc lie below 0.5 or above 2, it is gap graded. Thus, it was found from the Particle size distribution curve (PSD) that the Indus River Sand is gap graded as shown in the PSD curve below.





2.1.6 Aluminum powder

Aluminum powder is used in this study as an aerating agent in this study. It was obtained from Karachi. It reacts with calcium hydroxide in the cement in the presence of water, it releases hydrogen gas, that creates air voids in aerated concrete [13]. The quantity of aluminum was decided by hit and trial method starting at 0.2% of the weight of cement used. After many hits and trials, when max compressive strength at minimum density was found, aluminum quantity was obtained as 0.5%.

2.1.7 Water

Water is an important ingredient in any type of concrete. Water used in this study was free from pollutants and it was normal portable water.

2.2 Methodology

The major steps followed in this study are illustrated flowchart below. This study aims to determine the suitability of using fly ash and Indus River Sand in non-autoclaved aerated concrete. To achieve this, a total of 45 cubes were cast to check the compressive strength, water absorption and dry density of non-autoclaved aerated concrete. These cubes were prepared with varying percentages of Indus River Sand replacement with fine aggregates, i.e. (0%, 10%, 15%, 20%. and 25%) and cured using the conventional method for 7, 14, and 28 days respectively. As per ASTM C1693-11, cube dimensions were 100mm x 100mm (4”x4”). To achieve maximum compressive strength and minimum dry density, a series of trial-and-error test were conducted. Based on trial and error, the mix ratio was determined to be 1:1.5. The final mix included fly ash as 20% by weight of cement as partial replacement for cement, lime as 8% by weight of cement as an addition to cement and aluminum as 0.5% by weight of cement. The water/binder ratio was also determined by hit and trial, which was obtained as 0.6. The details of the mix design are presented in the following table.

Table 2. Mix Proportions of materials for Non autoclaved aerated concrete

S.NO	Mix ID	Cement (%)	Fly Ash (%)	Lime (%)	Natural Sand (%)	Indus River Sand (%)	No of Cubes	Water/ Binder Ratio
1	RF- 0	80	20	8	100	0	9	0.6
2	RS-10	80	20	8	90	10	9	0.6
3	RS-15	80	20	8	85	15	9	0.6
4	RS-20	80	20	8	80	20	9	0.6
5	RS-25	80	20	8	75	25	9	0.6

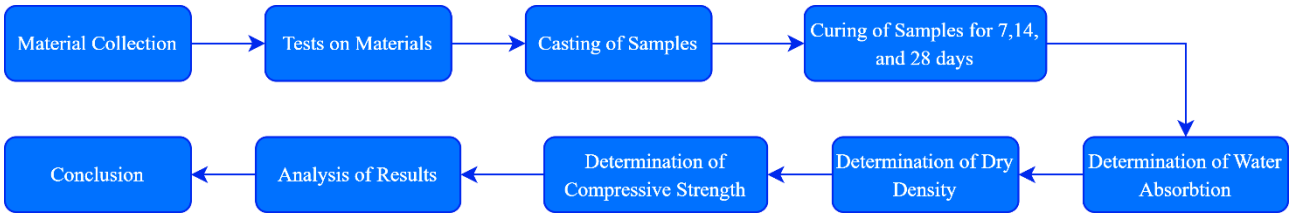
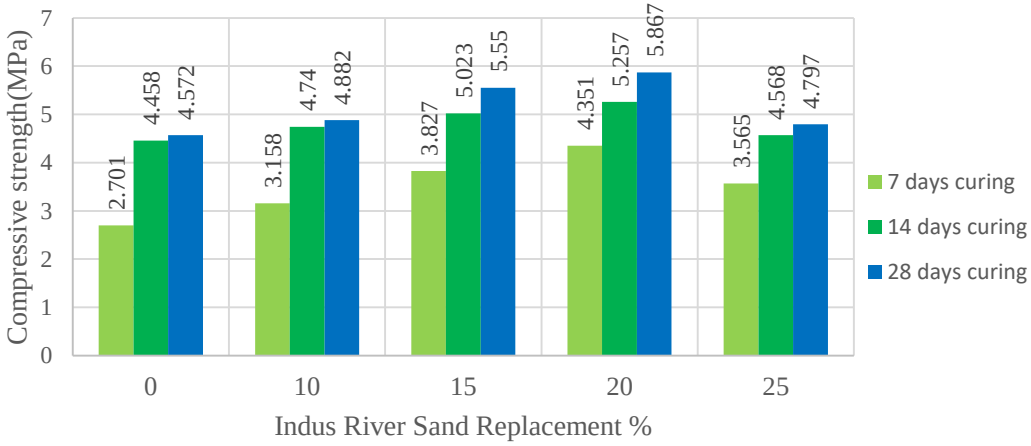


Fig. 1. Schematic Diagram of Research Methodology

3. Results and Discussion

3.1 Compressive Strength

The compressive Strength was determined by crushing the specimens in a universal testing machine (UTM) as per ASTM C1693-11 (reapproved 2017) [14].
Before testing, the cubes were cured in water for 7, 14 and 28 days respectively. After curing, these cubes were placed in an oven for 24 hours to ensure complete drying. After 24 hours, when cubes were

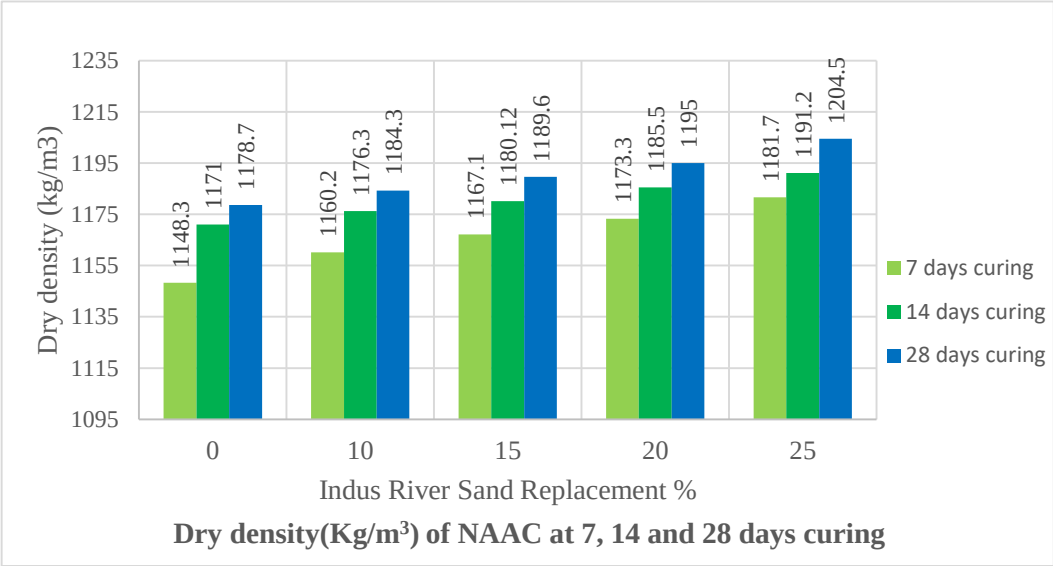


Compressive strength(MPa) of NAAC at 7, 14 and 28 days curing

completely dried, the compressive strength test was performed on cubes by applying loads on the cubes until failure in an UTM and this load was noted. Compressive strength is calculated by dividing the applied load per cross sectional area of the cubes. It can be observed from the given chart that by replacing both fly ash and Indus River Sand with cement and fine aggregates respectively, the compressive strength increases. From the graph, it is evident that the maximum compressive strength occurs at 20% Indus River sand replacement. Beyond 20% replacement of Indus River Sand, the compressive strength begins to fall. The maximum compressive strength recorded at 20% replacement for 7,14, and 28 days of curing was 4.351 MPa, 5.257 MPa and 5.867 MPa respectively.

3.2 Dry Density

The dry density of non-autoclaved aerated concrete was determined with the help of a weighing machine and a measuring scale. First, all the cubes were cured for 7,14 and 28 days respectively. When curing of cubes completed, these cubes were taken out of the curing tank and placed in an oven for 24 hours to ensure complete drying. After complete drying, densities of cubes were determined by simply weight per volume of oven dried cubes.

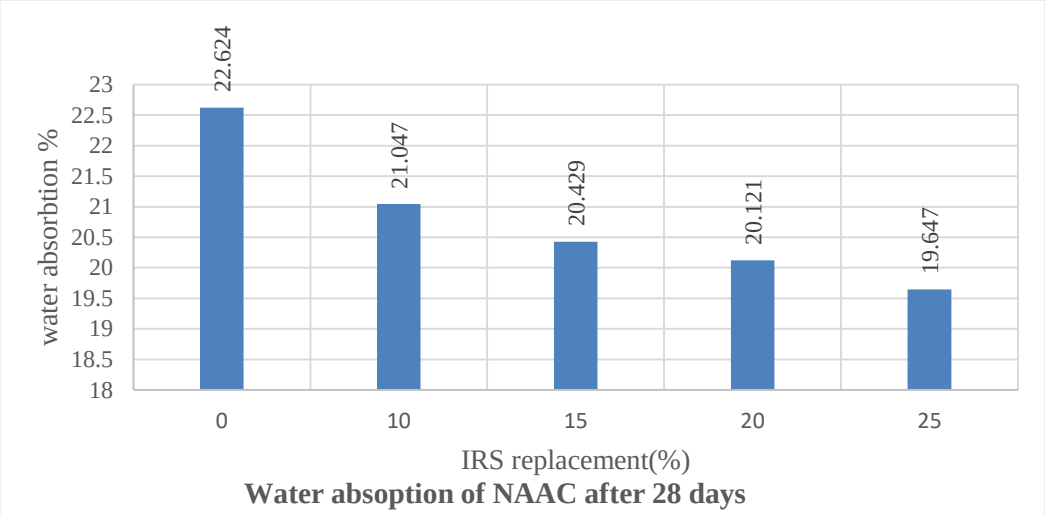


Dry density(Kg/m^3) of NAAC at 7, 14 and 28 days curing

From the chart, maximum dry densities were obtained at 25% replacement of Indus River Sand and after 28 days of curing. Maximum dry densities obtained at 25% replacement of the Indus River Sand for 7, 14, and 28 days of curing were 1181.7 Kg/m^3, 1191.2 Kg/m^3 and 1204.5 Kg/m^3 respectively.

3.3 Water Absorption

The water absorption test for non-autoclaved aerated concrete was performed as per ASTM C1693-11(Reapproved 2017) by using a weighing machine and an oven. The cubes were cured for 28 days. After completing the curing period, these cubes were taken out of the curing tank, the weight of each cube was noted then all the cubes were placed in an oven for 24 hours to ensure complete drying. After 24 hours, when the cubes dried completely, the water absorption of cubes was determined. The values of water absorption are illustrated in the chart below.



Water absoption of NAAC after 28 days

From the chart, the maximum value of water absorption was obtained at 0% of Indus River Sand Replacement and the minimum value of water absorption was obtained at 25% of Indus River Sand Replacement after 28 days of curing. The maximum and minimum values of water absorption obtained were as 22.624% and 19.647% respectively.

4. Conclusions

This study leads to following conclusions:

1- The compressive strength of non-autoclaved aerated concrete is enhanced by using fly ash and Indus River Sand. The highest compressive strength was achieved at 20% of Indus River Sand replacement after 28 days of curing, the compressive strength increased from 4.572 MPa to 5.867MPa, representing a 22.07% increment. The compressive strength began to fall if replacement of the Indus River Sand was beyond 20%. This indicates that 20% of Indus River Sand is the optimum proportion to enhance the compressive strength of non-autoclaved aerated concrete.

2- The dry density of non-autoclaved concrete enhanced by partially replacing natural sand with Indus River Sand. The maximum dry density was achieved at 25% replacement, which was 1204.5 kg/m^3 after 28 days of curing. This illustrates that by increasing the content of the Indus River Sand, the dry density of non-autoclaved aerated concrete improves. However, beyond 25% replacement, more testing is needed to determine its impact on the mechanical properties of non-autoclaved aerated concrete.

3- The water absorption of non-autoclaved concrete decreased as the content of Indus River Sand replacement is increased from 0% to 25%. The maximum value was obtained at 0% which was 22.624% and the minimum value was obtained at 25%, which was 19.647%. The reduction in water absorption illustrates that Indus River Sand particles have smaller particle size, which enhances the density and reduces the porosity, making it less permeable to water.

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Subject: Transportation and Infrastructure Engineering
Theme: Pavement Design, Maintenance, and Sustainability

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INVESTIGATION OF THE IMPACT OF POLYESTER ON THE CONVENTIONAL PROPERTIES OF BITUMEN

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ABSTRACT: Bitumen is primarily used in road construction and serves as a binding material in asphalt. However, its engineering performance is often compromised, limiting its efficiency and sustainability in the construction industry. The incorporation of polyester, specifically in the form of polyethylene terephthalate (PET), enhances the longevity of roads. Given that PET-based plastic waste constitutes a significant portion of global waste, its utilization as an additive in road production presents a viable recycling solution. This study aims to reduce plastic waste while improving the properties of bitumen by using PET as a modifier. For the experiment, PET plastic bottles were ground into a fine powder and incorporated into bitumen at varying concentrations of 2%, 4%, 6%, and 8% by weight. The modified and conventional bitumen samples were then subjected to laboratory tests. Experimental findings indicate that polyester affects bitumen both positively and negatively. However, the results demonstrate that the addition of PET significantly enhances bitumen's mechanical and physical properties, including tensile strength, water resistance, and overall durability.

KEYWORDS: asphalt binder, bitumen modification, polyester, PET bottles, waste recycling.

1. Introduction

1.1 General

As we know, bitumen has been used in construction since ancient times. Bitumen is mostly used in road construction as a binding material in asphalt pavement, and bitumen is used to convert any pervious layer into an impervious layer. We get the bitumen from the distillation process of crude oil, and that is known for its waterproofing and adhesive properties [1]. Distillation is the process in which lightweight gasoline and diesel are removed from the crude oil and leave heavier bitumen there. After the distillation process, it can be refined as well to improve its grade. Bitumen can occur naturally as well at the bottom of ancient lakes. Where prehistoric organisms have been present there from so many decades and have faced heat and pressure. Bitumen is composed of complex hydrocarbons with elements like calcium, iron, sulfur, and hydrogen [2]. The price of bitumen heavily depends on the recent price of crude oil. But there are some disadvantages of bitumen as well, it affects our environment so badly that bitumen plays a very major role in air pollution, especially in sunny and hot places. There are disadvantages for workers as well the fumes produced from it can cause cough, skin rashes, eye irritation, and lung problems [3]. On the other side, the waste

produced in the world is increasing to a large extent, creating ecological degradation and environmental pollution. Many researchers work day and night to recycle that waste material in bitumen to reduce its cost and enhance its properties as well. Among all those waste materials, one of them are polyester (PET plastic), which can be replaced with bitumen in order to make it economical and enhance its properties as well [4]. Polyethylene terephthalate (PET) is a waste plastic, in the form of water and beverage bottles, we will use them in bitumen.

Unmodified bitumen is highly viscous liquid and its tendency to be come's brittle at low temperature and gets soft at high temperature has limited its use form past many years or we can say decades' bitumen has been successfully used in asphalt concrete in road pavements [5]. Instead of continuous improvement of bitumen production process, mix design and pavement design, there are limits to use the bitumen in the road pavements design. So that's why we will try to modify the bitumen. Modified bitumen can provide real benefits to highway/motorway roads in order to its maintenance, handling of bitumen and construction work as well in terms of durability, efficiency and comfort of highway roads. Addition of polyester (PET) in bitumen can change the physical properties of bitumen, addition of PET can modify the properties like softening point and durability of bitumen. It will affect the penetration property as well [6], [7].

Table 1. Properties of Bitumen

S. No	Property	Description
01	Adhesive property	Bitumen is frequently used as a binder in asphalt pavement and other building products due to its powerful adhesive qualities.
02	Viscosity	Bitumen is very sticky and thick, making it challenging to manage and move in its native state.
03	Water resistance	Bitumen is used frequently in buildings as a waterproofing substance because of its high water resistance.
04	Thermal property	Bitumen has strong thermal characteristics and can endure high temps without melting or disintegrating.
05	Chemical resistance	Bitumen has a great level of resilience to many chemicals, including acids and alkalis.
06	Durability	Bitumen is a resilient substance that can endure significant wear and strain without degrading.
07	Elasticity	Bitumen has a high degree of elasticity and can be bent and stretched without fracturing. It is perfect for use in sealing and roofing uses because of this characteristic.
08	Weather resistance	Weather resistance: Bitumen is immune to deterioration and can endure prolonged contact with the elements.

1.2 Properties of Polyester PET.

Polyester (PET) has several key properties that make it preferable for a variety of applications. PET is a very strong, durable, lightweight material, has a high strength-to-weight ratio, is a transparent and versatile plastic, it is typically resistant to corrosion and chemicals, has a low thermal and

electrical conductivity, it is very pliable and easy to handle, it has fewer toxicity levels as compared to other plastics and the barrier properties which it delivers are impeccable [8].

2. Materials and Methodology

2.1 Bitumen

Bitumen is a very thick, dark-coloured hydrocarbons composite that is either obtained naturally or produced by refining gasoline. It is of hydrocarbons, mainly comprised of big molecules known as asphaltenes. Bitumen is frequently used in projects like building roads, roofing, waterproofing, and others that call for a strong, impervious substance. Additionally, it serves as an adhesive and sealant in a variety of industrial uses, as well as a binder in the asphalt concrete used to make road surfaces. In this study, 60/70 penetration grade bitumen is used as the base material due to its balanced hardness and flexibility, making it suitable for road construction and pavement applications.

2.2 Waste Polyester PET

Waste polyester includes discarded polyester-based products like clothing, packaging, and plastics. Proper recycling is crucial to prevent environmental harm. This study focuses on PET bottles, the most common polyester thermoplastic, made from ethylene glycol and terephthalic acid. PET is strong, lightweight, and widely used in textiles, containers, and engineering resins. In 2016, global PET production reached 56 million tons, with 30% used for bottles. This research examines adding polyester to bitumen in 2%, 4%, 6%, and 8% proportions to assess its impact on penetration, softening point, ductility, and viscosity.

Figure 1. Waste Polyester in form of PET Bottles

2.3 Physical and mechanical properties of waste polyester (PET Bottles)

Table 2. Properties of PET bottles

S #	Properties Indicator	Result
01	Tensile Strength (MPa)	8.89
02	Frost Resistance (^{O}C)	-44.8
03	Elongation at Break (%)	212

2.4 Tests on Modified Bitumen

Tests are an essential aspect in the manufacture and application of bitumen, Tests assist in ensuring that bitumen produced or utilized satisfies certain quality criteria and functions as expected in its intended use. Manufacturers and users can choose the right bitumen grade by performing these tests. Organizations like ASTM, Asphalt Institute, British Standards Institute, and ISI have

advised a variety of physical tests to assess the robustness of these binders.

2.4.1 Penetration value test

The penetration test of bitumen is a widely used method to determine the hardness or consistency of bituminous materials, following the ASTM D5 [9] standard. Determines by measuring the depth (in tenths of mm) a standard needle penetrates under a 100g load at 25°C for 5 seconds. Higher values indicate softer bitumen, which is suitable for colder climates.

2.4.2 Ductility test

Measures the stretchability of bitumen by pulling a sample at 5 cm/min at 25°C until it breaks. Higher ductility ensures better flexibility and resistance to cracking, essential for pavement durability followed by ASTM D113 [10].

2.4.3 Softening point test

The softening point test of bitumen, conducted as per ASTM D36 [11], involves placing Bitumen into a brass ring, and a steel ball is placed on top. The setup is heated at 5°C per minute in water or glycerin, and the temperature at which the softened bitumen allows the ball to fall 25 mm is recorded as the softening point

2.4.4 Specific Gravity test

A pycnometer is weighed empty, filled with water, and then with bitumen. The specific gravity is calculated by comparing the mass of bitumen to the mass of an equal volume of water at a standard temperature according to ASTM D70 [12].

2.4.5 Flash point test.

A bitumen sample is heated in an open cup (ASTM D92) or closed cup (ASTM D93) at a controlled rate. A small test flame is introduced at regular intervals, and the temperature at which vapors ignite momentarily is recorded as the flash point. This indicates the lowest temperature at which bitumen can release flammable vapors, ensuring safe handling and storage.

2.4.6 Fire point test.

After determining the flash point, heating continues, and the flame is repeatedly introduced. The fire point is the temperature at which vapors ignite and sustain combustion for at least 5 seconds. This value helps assess bitumen's thermal stability and fire hazard risks during heating and application by ASTM D92/D93 [13], [14].

2.5 Methodology Flow Chart

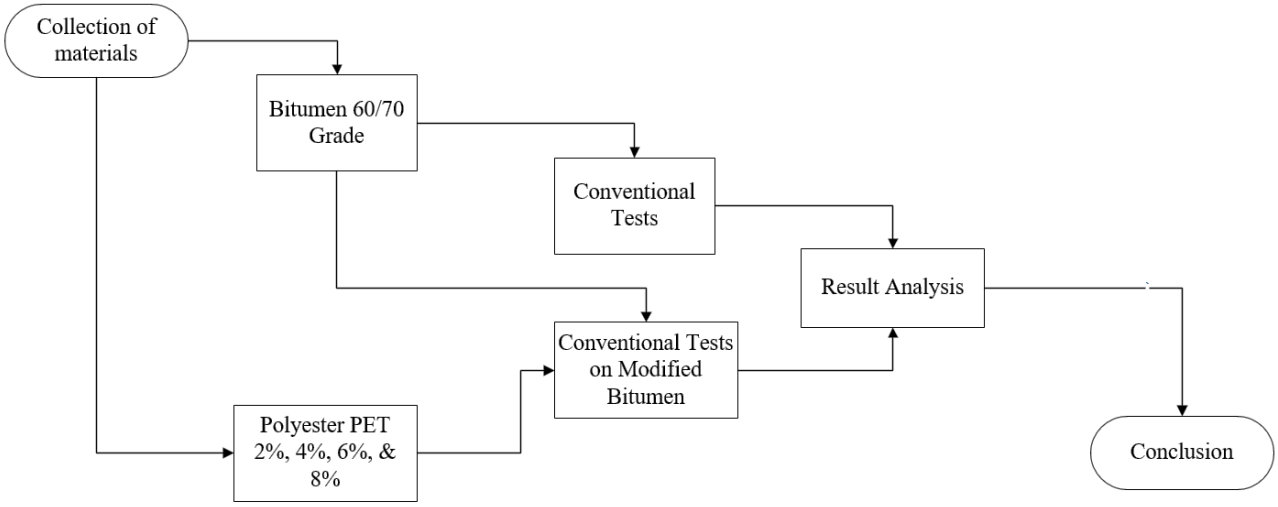

Figure 2. Methodology Chart

3. Results and Discussion

3.1 Effect of Polyester on Penetration Value.

The penetration test results indicate a significant change in the consistency of bitumen with the incorporation of polyester. As the percentage of polyester increased, the penetration values showed a decreasing trend, suggesting improved stiffness and reduced susceptibility to deformation. The optimum polyester content of 6% resulted in a penetration value of 69.33mm, which is within the acceptable range for flexible pavement applications. The reduction in penetration values signifies enhanced resistance to temperature variations and traffic loads.

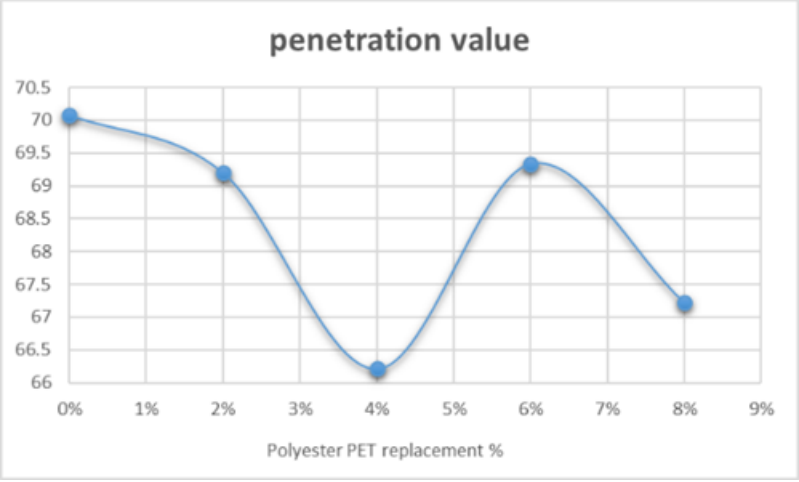

Figure 3. Penetration Value Graph.

The decreasing trend in penetration values suggests that polyester-modified bitumen exhibits greater resistance to deformation under load. This characteristic is particularly beneficial in warm

climates where bitumen softening is a concern. The findings align with previous studies on polymer-modified bitumen, confirming that the addition of polyester enhances structural stability.

3.2 Effect of Polyester on Specific Gravity.

The specific gravity of bitumen exhibited slight variations with the incorporation of polyester. The changes in specific gravity can influence the density and compaction characteristics of bitumen mixtures. The optimum polyester content resulted in a specific gravity of (Insert Value).

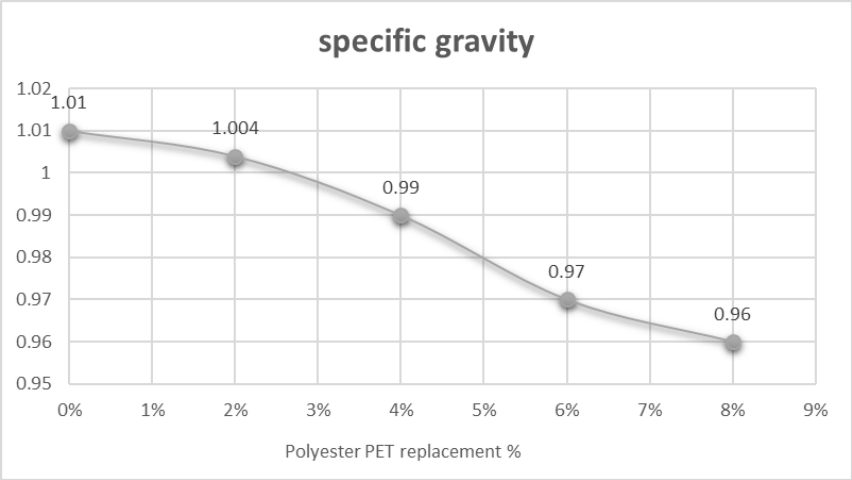

Figure 4. Specific Gravity Graph

The variation in specific gravity with polyester modification suggests minor changes in the density of bitumen, which can impact mix design considerations. While the changes are not drastic, it is essential to account for them when determining material proportions in pavement construction. The results indicate that polyester-modified bitumen remains within standard specifications for road applications.

3.3 Effect of Polyester on Ductility Value.

The ductility of bitumen decreased with the addition of polyester. A decrease in ductility suggests increased stiffness, which may reduce the flexibility of bitumen. However, the optimum polyester content of 6% (110.2 cm) maintained a balance between stiffness and flexibility, ensuring adequate performance under loading conditions. The observed reduction in ductility can be attributed to the polymeric nature of polyester, which alters the molecular structure of bitumen.

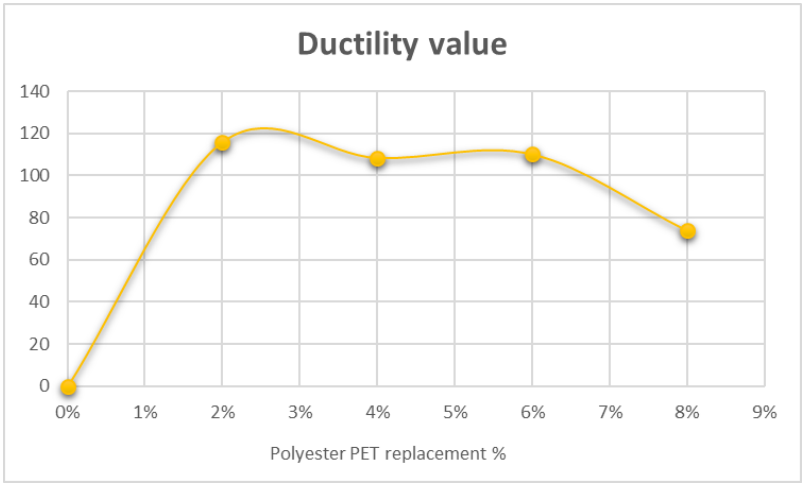

Figure 5. Ductility Value Graph.

While a decrease in ductility is observed, the reduction is within acceptable limits for pavement applications. Excessive stiffness may lead to brittleness; therefore, the optimum polyester content must be carefully selected to maintain a balance between flexibility and strength. The modified bitumen demonstrates improved resistance to permanent deformation, ensuring better long-term performance.

3.4 Effect of Polyester on Softening Point Value.

The addition of polyester led to an increase in the softening point of bitumen. A higher softening point implies improved resistance to rutting at elevated temperatures. The maximum softening point was observed at (8%), with a value of (52.3 °C). This improvement suggests that modified bitumen can better withstand high-temperature conditions, thereby enhancing the pavement's service life.

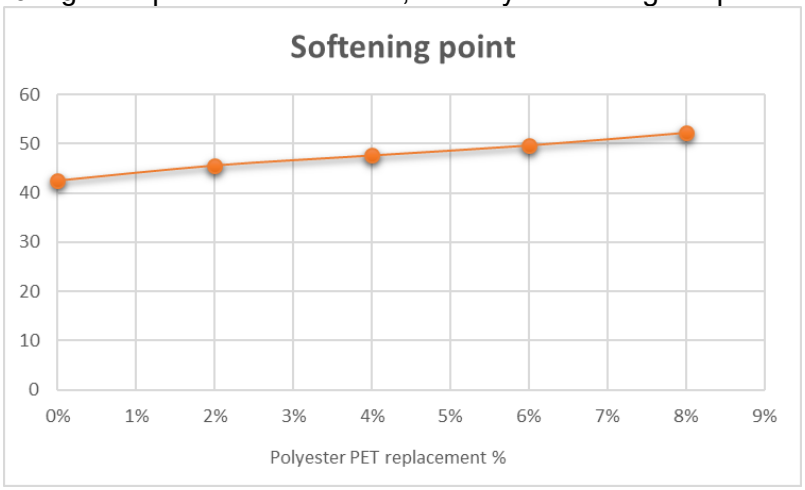

Figure 6. Softening Point Graph

An increase in the softening point indicates that the modified bitumen has a higher heat resistance,

making it more suitable for regions with high temperatures. This enhancement reduces the likelihood of pavement deformation and increases its durability, making polyester an effective modifier for improving

3.5 Effect of Polyester on Flash and Fire Point.

The flash point and fire point of bitumen increased with the addition of polyester. A higher flash point ensures safer handling and storage, while a higher fire point indicates improved resistance to ignition at elevated temperatures. The optimum polyester content resulted in a flash point of 291.3 °C and a fire point of 321.2 °C.

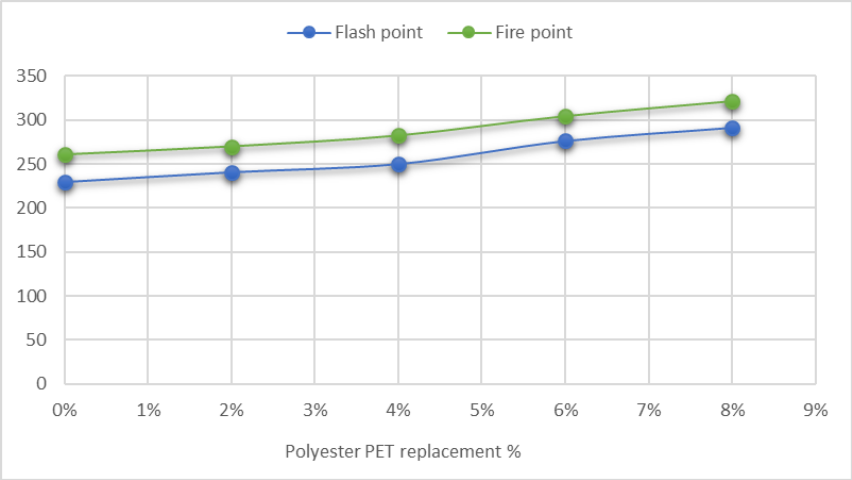

Figure 7. Flash and Fire Point Graph

The increase in flash and fire points suggests that polyester-modified bitumen is less prone to early ignition, making it safer for transportation and storage. This enhancement is particularly beneficial in high-temperature environments where fire hazards are a concern. The results confirm that polyester modification contributes to the thermal stability of bitumen.

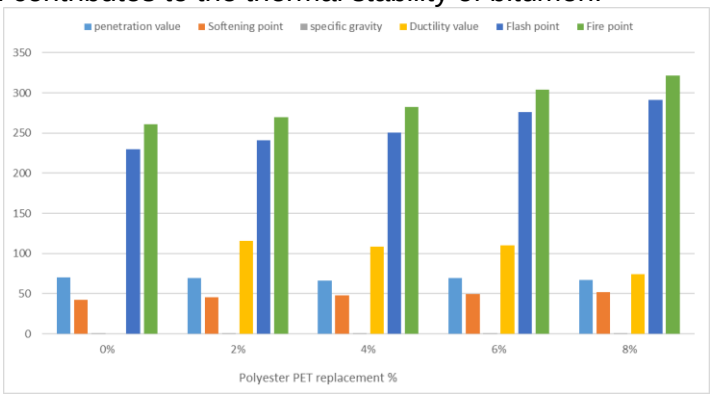

Figure 8. Combined Results Graph

From the experimental findings, it is evident that polyester-modified bitumen exhibits improved thermal stability, reduced susceptibility to deformation, and enhanced stiffness. However, excessive

polyester content may lead to excessive stiffness, which can impact the flexibility of the pavement. The optimum polyester content was determined to be 6%, which provided the best balance between all conventional properties.

4. Conclusion

1. The incorporation of polyester into bitumen significantly improves its conventional properties, enhancing its performance in pavement applications.
2. The penetration value decreases with the addition of polyester, indicating increased stiffness and reduced susceptibility to deformation.
3. The softening point increases, making the modified bitumen more resistant to high-temperature conditions and reducing the risk of rutting.
4. The ductility of modified bitumen decreases, but an optimum balance between flexibility and strength can be achieved with controlled polyester content.
5. The flash point and fire point of modified bitumen increase, making it safer for handling, storage, and transportation by reducing flammability risks.
6. The specific gravity of bitumen exhibits slight variations, which can impact mix design considerations but remains within acceptable limits for road construction.
7. Overall, polyester-modified bitumen demonstrates enhanced durability, improved thermal stability, and better resistance to traffic loads, making it a promising material for flexible pavements.
8. Excessive addition of polyester may lead to excessive stiffness; therefore, an optimum content must be determined to achieve the best balance between performance and workability.
9. Future studies should focus on long-term field performance evaluation of polyester-modified bitumen to validate laboratory findings and optimize usage for practical applications.

Acknowledgment

I sincerely thank my advisor, Engr Izzat Ali Sahito, for their guidance and support. I am also grateful to Department of Civil Engineering MUET Jamshoro for providing essential resources. Special thanks to my friends and colleagues for their encouragement, and to my family for their unwavering support.

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Subject: Structural and Geotechnical Engineering

Theme: Advanced Construction Materials and Technologies

Ref: 1st ICSIID//KHP/38

Development of Lightweight Concrete Containing Pumice Stone as Fine Aggregate in Presence of Polypropylene Fiber for Sustainable Construction

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ABSTRACT

This study explores the development of lightweight concrete using pumice stone as a fine aggregate in the presence of polypropylene (PP) fibers. Five mixes were prepared by replacing fine aggregates with pumice at 0%, 25%, 50%, 75%, and 100%. The workability, density, and compressive strength were evaluated. Results showed an increase in slump values with higher pumice content due to its round texture. A decrease in compressive strength was observed due to pumice's porosity. However, the optimal performance was observed at 50% replacement. The study confirms pumice's viability as a lightweight aggregate in structural and non-structural applications.

KEYWORDS: Compressive Strength, Density, Lightweight Concrete, Polypropylene Fiber, Pumice Aggregate

1. Introduction

Concrete is the most widely used construction material, composed of cement, fine aggregates, coarse aggregates, and water. The growing scarcity and environmental impact of natural aggregates has prompted the exploration of alternative materials. Pumice stone, a lightweight volcanic rock, shows promise as a fine aggregate due to its low density and thermal insulation properties. However, its high porosity can lead to reduced mechanical strength. The addition of polypropylene (PP) fibers can help mitigate this weakness by improving crack resistance and ductility. This study investigates the combined use of pumice stone and PP fibers in lightweight concrete to achieve a balance between strength, workability, and weight reduction.

1. Materials and Methodology

1.1 Materials

Ordinary Portland Cement (OPC) was used as the binding material. Locally available Bulari sand served as fine aggregate, while coarse aggregates were crushed stones conforming to ASTM grading. Pumice stone, sourced from Lahore, replaced fine aggregates at varying levels. Polypropylene fibers were added at 0.025% by weight of cement. The water-cement ratio was maintained at 0.5.

1.2 Mix Proportions

Five concrete mixes were prepared: a control mix and four mixes with 25%, 50%, 75%, and 100% replacement of fine aggregates with pumice. Each mix contained 0.025% PP fiber. The mix ratio was 1:2:4 (cement: fine aggregate: coarse aggregate) with weight batching.

1.3 Testing Procedures

Workability was tested using the slump cone method (ASTM C143). Cubes of size 150×150×150 mm were cast and cured for 7 and 28 days. Density was measured per ASTM C138 and compressive strength using a Compression Testing Machine (CTM) according to BS 1881-116.

Table 1 : Total Number of Specimen Required for the Study

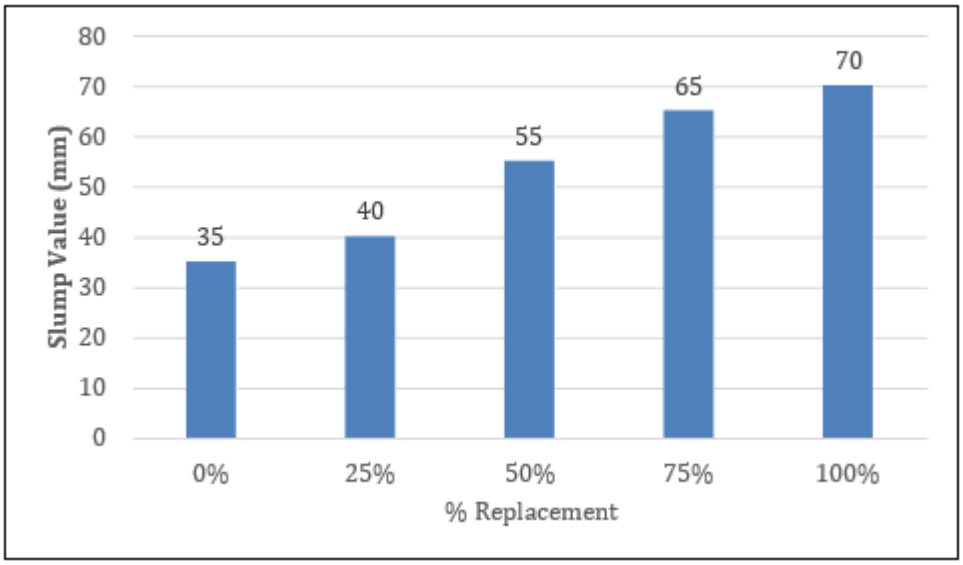
Code	OPC %	Pumice Stone %	PP Fiber %	Fine Aggregate %	Coarse aggregate %	Compressive strength at 7 days	Compressive strength at 28 days
M1	100	0	0	100	100	3	3
M2	100	25	0.025	75	100	3	3
M3	100	50	0.025	50	100	3	3
M4	100	75	0.025	25	100	3	3
M5	100	100	0.025	0	100	3	3
Total Number of Samples						15	15

2. Results and Discussion

2.1 Workability

Slump tests revealed an increase in workability with higher pumice content. The slump value rose from 35 mm in the control mix to 70 mm at 100% replacement. This increase is attributed to the smooth, rounded texture of pumice which reduces internal friction among particles. The use of saturated surface- dry pumice also helped maintain consistent water content, supporting the increase in slump.

Figure 1: Workability of Concrete Containing Different Mix Proportions of concrete



3.2. Density

The density of concrete decreased as the percentage of pumice increased, due to its lower specific gravity. The density dropped from 2498 kg/m³ in the control mix to 1444 kg/m³ at 100% replacement, showing a 42% reduction. This makes the concrete suitable for lightweight applications where reduced self-weight is desirable.

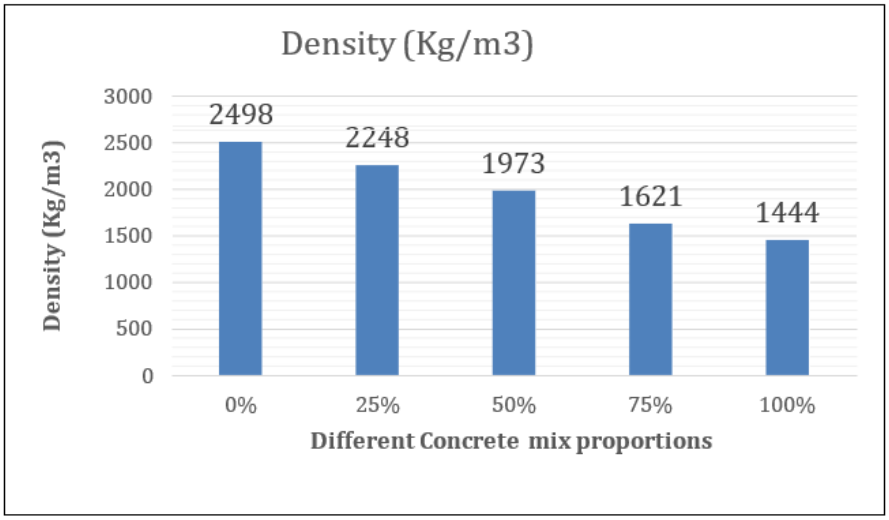


Figure 2: Density of Concrete containing different percentages of Pumice stone

3.3. Compressive strength

Compressive strength results showed a consistent decline with increasing pumice content. At 7 days, strength decreased from 14.18 MPa (0%) to 1.26 MPa (100%). At 28 days, the strength dropped from 16.93 MPa to 1.75 MPa. The 50% replacement mix showed a good compromise, achieving 8.35 MPa at 28 days. This strength is acceptable for non-load bearing elements and lightweight structural components. The reduction is primarily due to pumice's porosity and lower stiffness, as well as weaker bonding at the interfacial transition zone (ITZ).

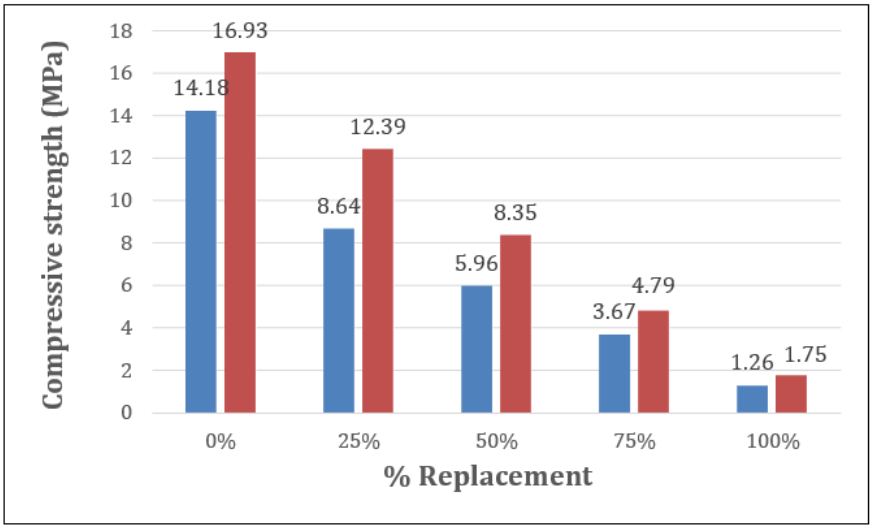


Fig 4: Combined Compressive Strength of Concrete cubes for 7 and 28 days

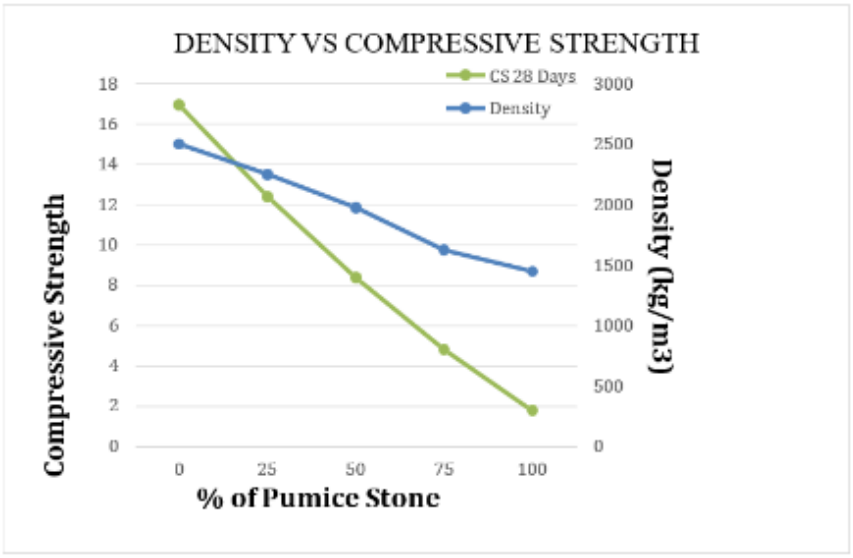


Fig 5: Comparative graph – Density Vs Compressive strength at 28 days

4. Conclusion

This study confirms that pumice stone is a viable lightweight aggregate for concrete. It improves workability and reduces concrete density, making it suitable for applications where weight reduction is critical. However, its use leads to reduced compressive strength, particularly at higher replacement levels. A 50% replacement of fine aggregate with pumice stone in the presence of 0.025% PP fiber achieved a good balance between reduced weight and acceptable strength.

Acknowledgment

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Subject: Structural and Geotechnical Engineering

Theme: Sustainable and Resilient Structural Systems

Ref: 1st ICSIID//KHP/42

Combined Effect of Coal Bottom Ash and Polypropylene Fibers on Mechanical Performance of Self-Healed Concrete

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Abstract:

Though naturally weak in tension, concrete shows great compressive strength, which makes it prone to cracking. These cracks not only affect serviceability but also undermine the structural integrity. The self-healing method has attracted much interest as a way to fix cracks, so improving both strength and durability while also supporting energy efficiency and prolonging the useful life of buildings. Using coal bottom ash (CBA) as a partial substitute for natural fine aggregate, the self-healing potential of concrete was explored in this work. CBA, because of its pozzolanic qualities, interacts with calcium hydroxide to create calcium silicate hydrate (C-S-H), which fills gaps and improves concrete performance with time. Apart from strengthening the structural integrity of the material, this method encourages cost efficiency and preserves natural resources. Using a concrete mix ratio of 1:2:4, Type-I cement, fine aggregate passing through a #16 sieve, coarse aggregate with a maximum size of 10 mm, and polypropylene fibers at 0.5% by volume were included. While a constant water-to-cement ratio of 0.40 was kept all through the research, CBA, passing through a #16 sieve, was used as a fine aggregate replacement at different levels (0–50%). Mechanical characteristics including compressive strength, split tensile strength, and modulus of rupture were measured at several healing times to assess the self-healing capacity. The experimental results showed that, together with fiber reinforcement, a 30% substitution of fine aggregate with CBA produced improved mechanical performance. Fibers' bridging action, which helps crack closure and offers enough moisture for the self-healing process, explains this enhancement. These findings lead one to believe that they may be usefully applied to concrete structures exposed to water, such dams and bridges, so enhancing strength and durability in the building industry.

Keywords: Coal Bottom Ash, Polypropylene Fibers, Cracking, Self-Healing, Mechanical Properties

1. Introduction

Concrete is used widely due to its strength and durability; yet, being brittle, it is prone to cracking, which compromises structures and hastens decay. Traditional methods of repair are laborious and costly. Self-healing concrete offers a novel approach by automatically patching cracks, so increasing durability. Its cementitious properties have made the use of pozzolanic materials like coal bottom ash (CBA) interesting among other methods. When CBA, a byproduct of burning coal, interacts with calcium hydroxide to produce C-S-H, concrete is strengthened and cracks are filled. Polypropylene fibers also help to heal by filling in gaps and retaining moisture. Particularly for infrastructure under severe conditions, this paper looks at how using CBA in place of certain fine aggregate would improve the sustainability and mechanical performance of concrete. A significant issue in concrete structures is cracking since it compromises lifetime and hastens decay. Self-healing concrete is a developing technology that solves this problem by allowing cracks to close naturally, therefore improving strength and serviceability. Several approaches have been investigated for self-healing, including microbial healing, encapsulated healing agents, autogenous healing, and pozzolanic material-based healing. The addition of pozzolanic materials, which interact with calcium hydroxide to generate C-S-H, filling fractures over time, is one of the most often studied methods for self-healing [1–3]. Research has revealed that fly ash, silica fume, and ground granulated blast-furnace slag (GGBS) are among materials that show self-healing qualities by reacting with free lime and producing more binding chemicals [4]. Another pozzolanic material drawing attention for its availability and capacity to enhance concrete performance is coal bottom ash (CBA). Unlike fly ash, which is gathered from flue gases, CBA is coarser and collects at the bottom of coal-fired boilers. Studies show that CBA can be used as a partial substitute for fine aggregates in concrete since it has cementitious characteristics [5,6].

Studies done before show that using CBA in place of fine aggregate improves the durability and mechanical characteristics of concrete. Unburnt carbon and aluminosilicates in CBA help the long-term pozzolanic reaction, which improves strength and crack closure. The ideal replacement ratio, though, differs with particle size distribution, chemical composition, and curing conditions [6]. The presence of fibres, which help to bridge fractures and keep the moisture required for the healing process [7,8], is another important element affecting self-healing. Particularly polypropylene fibres have been shown to increase tensile strength and promote autogenous healing. Studies indicate that controlling crack width and preserving internal moisture helps CBA with fibre reinforcement to improve self-healing efficiency V. Although the findings are encouraging, more research is required to identify the optimal CBA replacement levels and their influence on mechanical characteristics with time.

This study builds upon existing research by evaluating different CBA replacement ratios and assessing their influence on self-healing efficiency. The study intends to create a more durable and sustainable concrete mix appropriate for infrastructure uses exposed to water and harsh environmental conditions by means of CBA and fibres reinforcement optimization.

2. Experimental Program

2.1 Materials and Mix Proportions

Type-I cement, natural fine aggregate (passing through a #16 sieve), and coarse aggregate with a maximum size of 10 mm were used to prepare the concrete mix. At different degrees (0%, 10%, 20%, 30%, 40%, and 50%), coal bottom ash (CBA) was used as a partial substitute for fine aggregate. Polypropylene fibers were added at 0.5% by volume to improve crack bridging under a water-to-cement ratio of 0.40.

2.2 Specimen Preparation and Pre-Cracking

Different mechanical tests used standard molds to cast concrete samples. While prismatic specimens (100 mm × 100 mm × 500 mm) were cast for the modulus of rupture test, cylindrical specimens (150 mm × 300 mm) were prepared for compressive and split tensile strength tests. After 24 hours, the specimens were demolded and cured under regulated conditions. Every concrete sample was placed in a compression testing machine to generate fractures. At a very slow pace of 0.2 KN/sec, the load was applied. The load was applied extremely slowly; each specimen was loaded into a compression testing machine for pre-cracking. The loading was halted and the load value recorded when the surface of the specimen started to fracture. Every broken sample was photographed as shown in Figure 1 after it was cracked and then let to heal for 7, 28, and 56 days.

Figure 1: Crack details of samples with microscope (a) Cube specimen (b) Cylinder

2.3 Testing Methods

To assess the self-healing efficiency, the following mechanical tests were conducted at different curing intervals:

- **Re-Gain in Compressive Strength Test**: Performed using a universal testing machine (UTM) to evaluate the strength development over time as shown in Figure 2. Following equation was used to estimate the re-gain values for each mix.

$$Re - Gain\ in\ Compressive\ Strength = \frac{Compressive\ Strength\ after\ Healing}{Origional\ Compressive\ Strength} \times 100 \quad (1)$$

- **Re-Gain in Split Tensile Strength Test**: Conducted to assess the improvement in tensile properties due to fiber reinforcement and self-healing effects as shown in Figure 2. Following equation was used to estimate the re-gain values for each mix.

$$Re - Gain\ in\ Split\ Tensile\ strength = \frac{Tensile\ Strength\ after\ Healing}{Origional\ Tesnile\ Strength} \times 100 \quad (2)$$

Figure 2: Cube and cylinder specimen during pre-cracking stage

Additionally, the healing efficiency was analysed by observing crack closure under a microscope and measuring the recovery in mechanical properties after re-curing in water.

3. Results and Discussions

3.1 Re-Gain in Compressive Strength

Figure 3 shows values of compressive strength at every curing time as well as Re-Gain in compressive strength values for each mix with and without CBA.

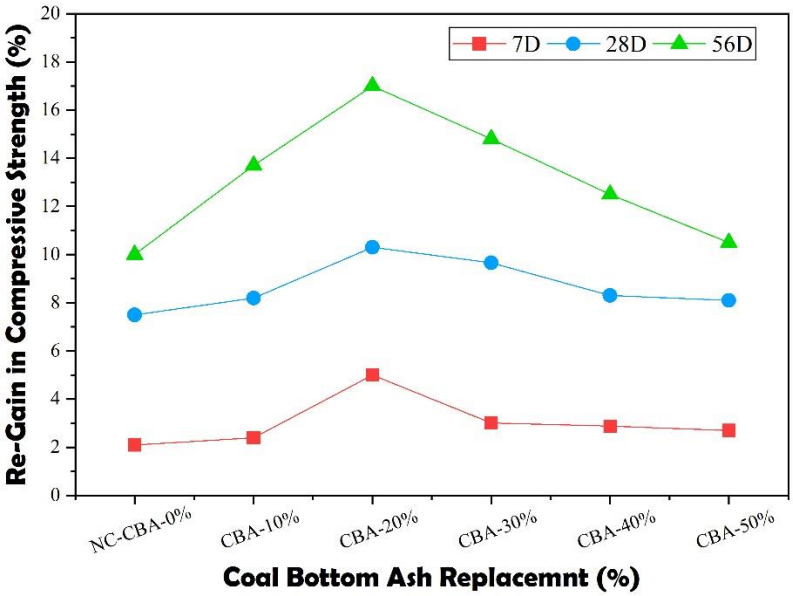


Figure 3: Re-gain in compressive strength at different healing duration

Figure 3 reveals the outcomes of every mix following different healing durations. One of the main objectives of this study was to investigate how industrial waste materials affect the self-healing capacity of high-performance fiber reinforced concrete. Adding coal bottom ash and polypropylene fibers in concrete, as shown in Figure 3, accelerates the healing process and enhances mechanical performance. The figure implies that mixes with coal bottom ash show a notable rise in compressive strength and the ideal value was 30% with fine aggregate substitution. At 56 days of healing time, the maximum value was 30% CBA replacement, or 17%.

3.1 Re-Gain in split tensile Strength

Figure 4 shows values of compressive strength at every curing time as well as Re-Gain in compressive strength values for each mix with and without CBA. A comparable kind of rise observed is shown in Figure 4. It's vital to emphasize that the addition of polypropylene fibers enhanced the tensile strength and the healing impact of fractures. Fibers are hydrophilic and tend to hold or absorb water for long periods, so they provide the required amount of moisture to sustain the hydration process, which is the main driver of crack healing and the creation of C-S-H gel inside the crack region, even in the absence of moisture.

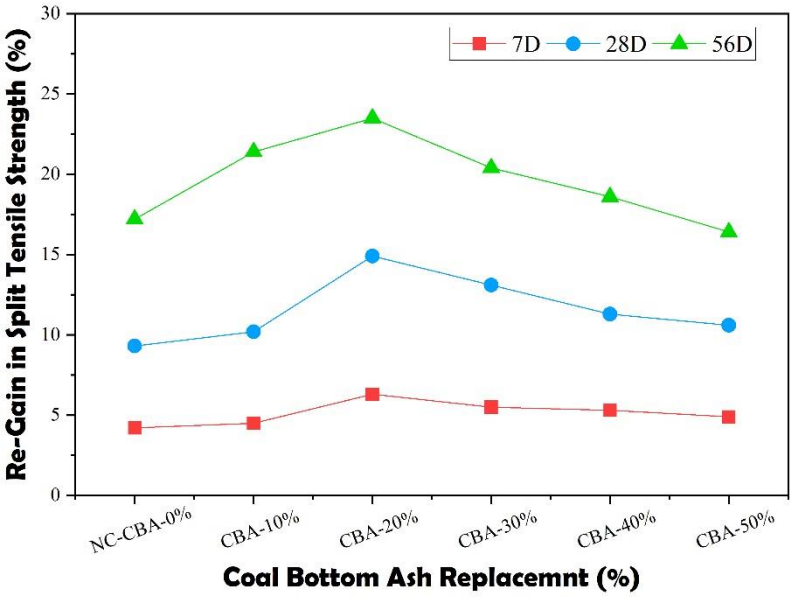
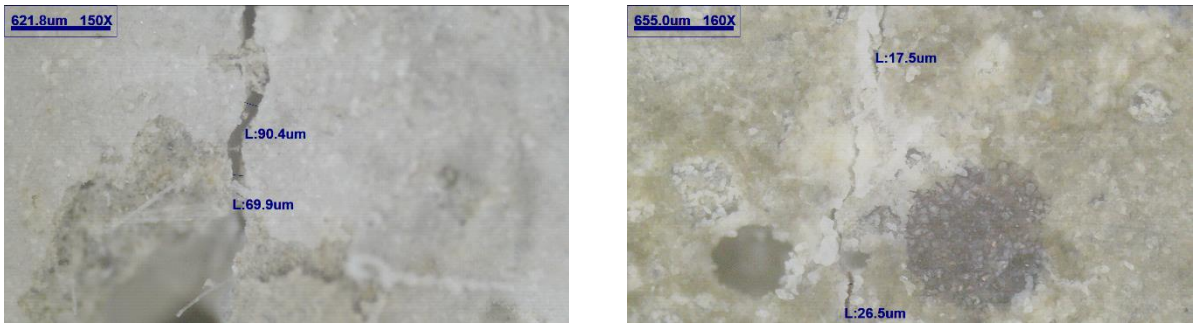


Figure 4: Re-gain in split tensile strength at different healing duration

The fact that the maximum rise in tensile strength was over 23% while the re-gain in compressive strength was under 20% shows the significance of PP fibers in raising the tensile capacity of concrete.

3.3 Microscopic Observation of Healed Specimens

Figure 5 shows healed specimens under microscopic examination. Test findings displayed in Figure 5 show that mixes including coal bottom ash and PP fibers had a notable crack-healing impact. These outcomes confirm the results displayed in Figures 3 & 4.



(a) Pre-Cracked Sample (b) Healed Sample

Figure 5: Microscopic Images of Specimen during (a) pre-cracking stage and (b) after 56 days of healing

Coal bottom ash and PP fibers have been shown to enhance crack healing in concrete by creating more calcium silicate hydrate (C-S-H) gel and generating calcium hydroxide (CH) during cement hydration. Efficiently filling in crack voids helps this secondary C-S-H gel to boost the resilience of the concrete and its self-healing capacity.

4. Conclusions

Using polypropylene fibers (PP fibers) for crack bridging and coal bottom ash (CBA) as a partial fine aggregate replacement, this work investigated concrete self-healing. The main results and uses are briefly outlined below:

- CBA replaced 30% of the fine aggregate and 0.5% PP fibers by volume, producing the best mechanical properties. After 56 days of healing, this combination showed 17% higher compressive strength and 23% higher split tensile strength, indicating that fibers and CBA improve self-healing.
- By bridging fissures and holding moisture, PP fibers encouraged hydration and calcium silicate hydrate (C-S-H) gel formation. This greatly enhanced tensile strength and crack closure. Filling crack voids, secondary C-S-H gel enhanced structural integrity and durability of the concrete.
- Partial CBA replacement for fine aggregate improved the self-healing, sustainability, and cost of concrete by using industrial waste and conserving natural resources. Eco-friendly construction techniques back this one.
- Concrete dams, bridges, and maritime infrastructure exposed to water or severe weather should take the study's results into account. Self-healing can reduce maintenance expenses, increase service life, and enhance the performance of these buildings.

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Subject: Structural and Geotechnical Engineering

Theme: Sustainable and Resilient Structural Systems

Ref: 1st ICSIID//KHP/44

COMPARATIVE ANALYSIS & DESIGN WITH COST ANALYSISOF BAHRIA TOWN BUILDING WITH & WITHOUT SHEAR WALL BY USING ETABS SOFTWARE (A CASE STUDY)

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Abstract
Structural engineers are primarily concerned with figuring out how a structure will behave when subjected to horizontal forces and different loads combinations and tall buildings require sufficient rigidity to withstand horizontal forces caused by wind, and other structural loads. And also large size of the columns making it uneconomical, to give the structure greater rigidity and make structure economical, shear walls is used that are added to the interior of the proposed structure. The analysis and modelling of the whole structure is done with important integrated software called ETABS (2018). A G+12 high-rise building in Karachi, Pakistan, is compared and designed using ETABS software, with a focus on structural safety and cost-effectiveness. This study looks at three different scenarios: a building without shear walls, a reduced column size that leads to structural failure and a designing with shear walls. To guarantee both performance and safety, the models were subjected to a range of load combinations. Shear walls cut the quantity of steel needed by 40%, according to cost calculations, making the design both cost-effective and structurally sound. This study emphasizes the critical role shear walls and lift wall play in high-rise construction while offering valuable insights into safe and cost-effective building design methods.

Keywords: High-rise, ETABS, Structure, Model, Cost-analysis, Shear-wall.

1. Introduction

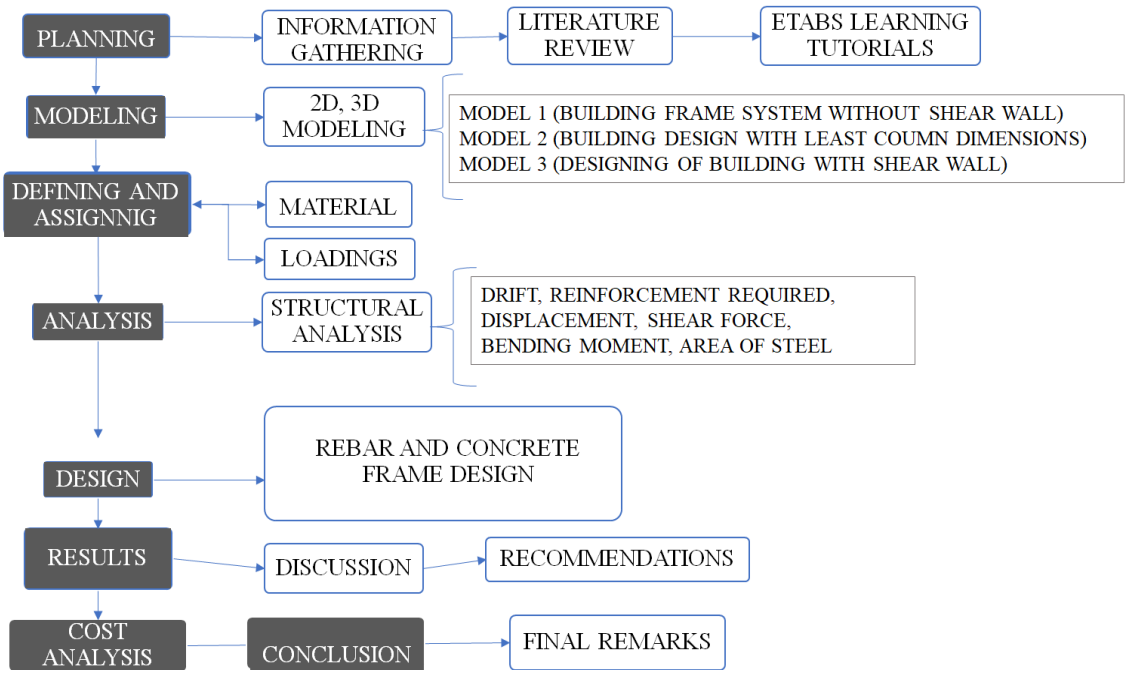
Traditionally, the Buildings were designed manually, which changed into a prolonged process, and the possibilities of human mistakes had been large. With time, the fashion within the buildings that were modified, and those commenced to transport closer to high-upward push buildings. This made it very tough to lay out such systems with the aid of using guide methods. Hence, special software had been added to the marketplace to fill the Gap. ETABS is one of the software that is used to layout any form of construction in the course of the world. In this thesis, a G+12 High Rise Building with and without shear wall has been taken for evaluation and layout by the usage of ETABS. This project integrates the modelling, analysis, and design of a G+12 high-rise building utilizing ETABS 2018 with

seismic and wind load assessments based on ACI regulations and the Building Code of Pakistan (BCP 2007). To ensure accuracy in the analysis and design process, the building's structural behaviour is simulated using the finite element approach. According to BCP 2007, Bahria Town, Karachi, Sindh, Pakistan, where the proposed reinforced concrete framed building is situated, is Seismic Zone 2-B, meaning it is at moderate risk. The building's many commercial uses, such as a shopping mall, retail establishments, offices and lift systems, necessitate a robust structural design that can withstand a range of loading scenarios. This study is to evaluate the effects of shear walls on stability, seismic resistance, and cost effectiveness by comparing the performance of the structure with and without shear walls. To assess deflections, material optimization, and structural safety, several load combinations are used. The findings will shed light on how well shear walls work in high-rise construction and offer useful recommendations for future building plans in seismically active areas.

2. Methodology

At the beginning of the study, a 3D structural model of a G+12 reinforced concrete high-rise structure is created using ETABS 2018. Examples of structural elements that meet ACI and BCP 2007 requirements include shear walls, beams, slabs, and columns. Numerous load scenarios, such as dead, live, wind, seismic, and various combinations of loads, are included in the study. The behaviour of the structure is evaluated using frame span loads, deformed shape, and wind response. A comparative analysis is carried out to assess the performance of the building with and without shear walls. A cost study is also conducted to determine the impact of shear walls on material consumption and overall building costs. The findings shed light on the most economical, reliable, and structurally sound design for tall buildings.

Fig.1. Tabular Form of Methodology



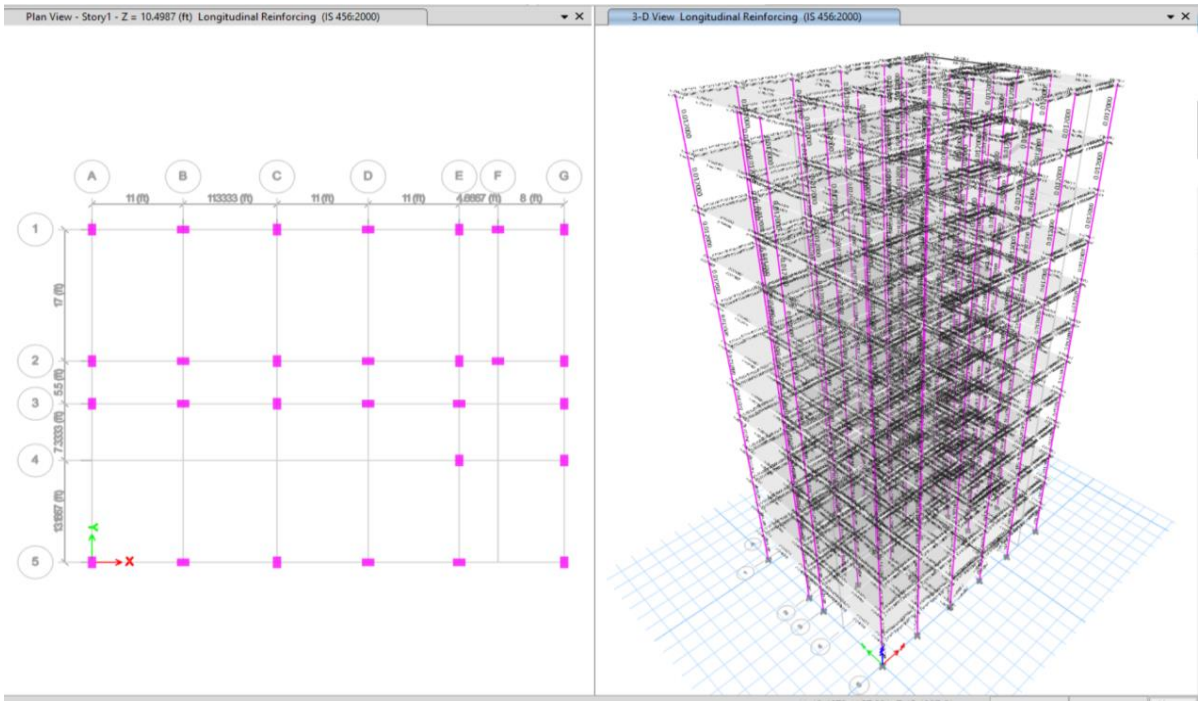
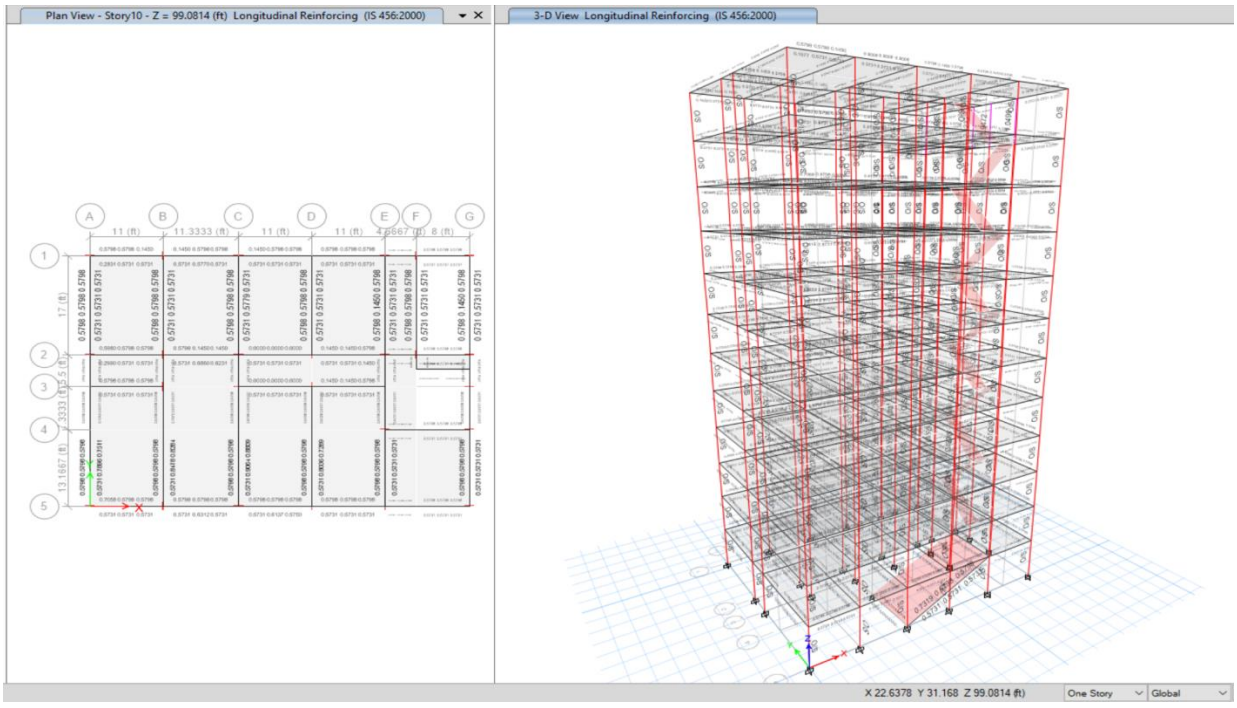


Fig.2. Plan & 3D model view of the building.

Fig.3. Plan & 3D view of the building with least column dimensions.


Plan View - Story10 - Z = 99.0814 (ft) Longitudinal Reinforcing (IS 456:2000)
3-D View Longitudinal Reinforcing (IS 456:2000)
X 22.6378 Y 31.168 Z 99.0814 (ft)
One Story
Global

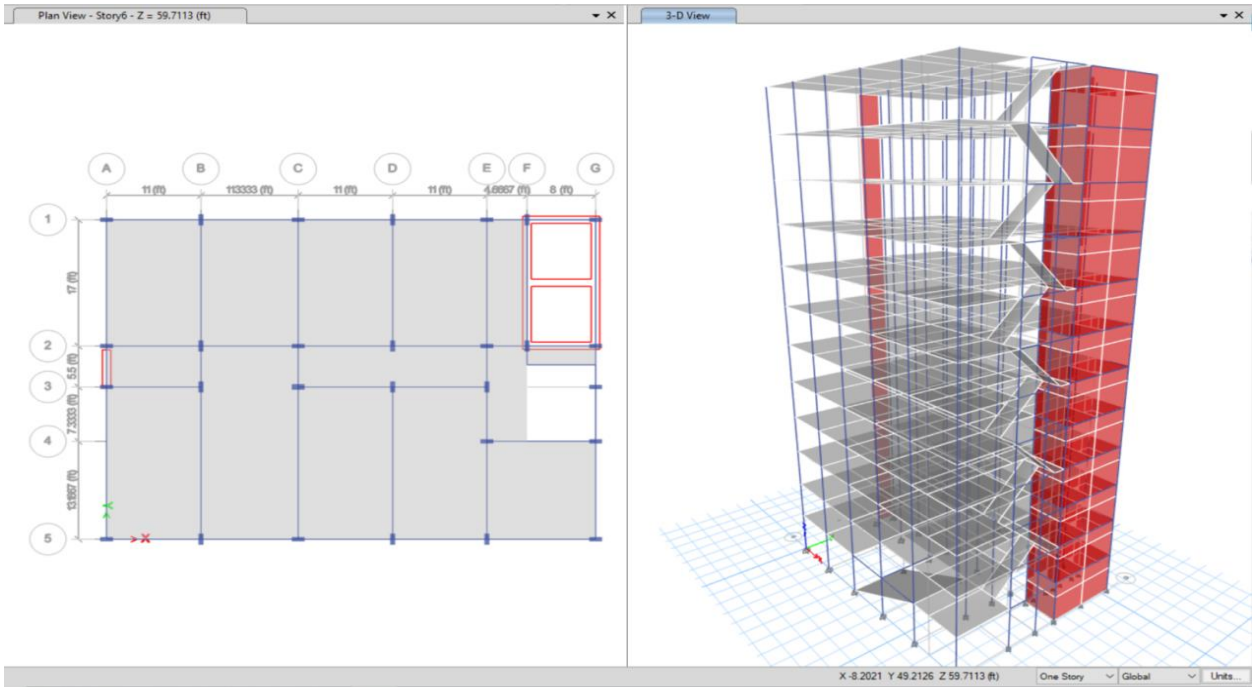


Fig. 4. Plan & 3D model view of the building with shear wall.

3. Results and Discussion

The total amount of steel reinforcement and concrete needed for columns was determined in Model 1. Model 3 reduced the size of the columns and calculated the total amount of concrete and steel needed for the lift walls, shear walls, and columns. Because the slab and beam sizes were the same in both models, the cost analysis was the same. In contrast to the 6,666,660 total cost of steel for Model 1, the total cost of steel for Model 3, which had lift and shear walls, was 3,940,119.04. According to this estimate, steel costs can be reduced by 40% by lowering column sizes and adding shear or lift walls. The shear wall model is therefore more cost-effective and structurally sound.

Table 1. Cost Analysis of both models.

1st Model						
Description	No	Length	Width	Height	Quantity	Units
1s Floor Columns	28	1	1.5	10	420	Cft
Total Concrete of columns	364	1	1.5	10	5460	Cft
Steel required	2.5 % of Total Volume of Concrete				30303	Kg
2nd Model						
Description	No	Length	Width	Height	Quantity	Units
1st Floor Columns	28	1	0.583	10	163.24	Cft
Total Concrete of columns	364	1	0.583	10	2122.12	Cft
Steel required	2.5 % of Total Volume of Concrete				11777.77	Kg
Shear Wall 1st Floor	1	5.5	0.75	10	41.25	Cft
Shear Wall Total Concrete	12	5.5	0.75	10	495	Cft
Required Steel in Shear Wall	1.5% of total volume of Concrete				1648.35	Kg
				Total Steel	13426.12	Kg
Lift Wall 1st Floor	1	17	0.66	10	112.2	Cft
Total Lift Wall Concrete	12	17	0.66	10	1346.4	Cft
Required Steel	1.5% of total volume of Concrete				4483.512	Kg
			Total Quantity of Steel		17909.632	Kg

4. Conclusion

ETABS was used in this study to examine the structural and financial feasibility of a G+12 high-rise structure with and without shear walls. The findings showed that while the building without shear walls was safe to load, it collapsed when the column size was reduced without additional lateral support. Shear walls increased the building's stability and resistance to lateral pressures like wind. According to the cost research, installing shear walls also greatly decreased the amount of steel used, which

resulted in a 40% decrease in overall construction costs. Because shear walls improve the structural robustness of high-rise structures while also making them more cost-effective, they are consequently recommended as a design strategy for seismically active places.

5. Acknowledgment

First and most of all, I would like to thank Almighty Allah for blessings and being with me in every step I pass through. I'm thankful to my Supervisor Engr. Danesh kumar for immense guidance and supervision all the way through this research work. Finally, I must express my very profound gratitude to my parents and family members for their constant support and encouragement throughout my years of study and life in general. This accomplishment would not have been possible without them. Thank you.

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Subject: Structural and Geotechnical Engineering

Theme: Foundations and Soil-Structure Interaction

Ref: 1st ICSIID//KHP/47

EFFECT OF A NORMAL FAULT RUPTURE ON A MULTI-STORY BUILDING RESTING ON A DEEP FOUNDATION

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Abstract

This study explores the impact of the normal fault rupture on multi-story building supported by the raft foundation using three-dimensional (3D) numerical modelling with ABAQUS software by using finite element method. The investigation employs three-dimensional finite element analysis, simulating a standard break with a 600-degree dip angle and a 60-centimeter length near a 20-story skyscraper on a 4 by 4 piled raft foundation in sand. The raft is a square structure measuring 15 meters in breadth and 1.5 meters in thickness, supported by a series of 4 by 4 piles spaced 3.75 meters apart at the centre. The computed results indicate a linear induced settlement in the building. Initially, at fault slip=0 cm, there is minimal differential settlement. However, as fault slip increases, the differential settlement also rises. At a 60-centimeter fault slip, the maximum movement is observed to be 400 mm. The highest lateral deflection occurs at the roof level of the twentieth story. Additionally, the head of P1 pile anticipates the highest negative bending moment of 100 kN-m.

Keywords: Fault rupture, Piled, ABAQUS, Raft Foundation, Story Drift.

1. Introduction

A fault is a fracture or a zone of fractures between two blocks of rock. Faults enable movement between these blocks, which can occur rapidly during an earthquake or gradually through processes like creep. The lengths of faults can vary from a few millimetres to kilometres, and throughout the geologic time, most faults have cause repeated displacements. The abrupt slipping of rock a side of the fault relative to other is a characteristic feature during earthquakes. Understanding these geological processes is crucial for making informed decisions about construction in seismically active regions. The rocks' internal strain is what leads to faults. When a formation experiences sufficient stress for a fault to rupture, strain results. [1]

The Blue Anchor Fault is depicted in Figure 1 and amply illustrates how strains can cause surface rupture. Numerous factors, including gravity, drying or wetting conditions, thermal expansion or contraction, and even mantle convection (plate tectonics), can cause stress. [2]

Fig. 1. The Blue Anchor Fault

Moreover, figure 2 shows the components of a fault rupture along with proper illustrations and labelling dip. The four main categories of errors are as follows:

a) Normal Faults
b) Reverse Faults
c) Strike-slip Faults
d) Oblique Faults

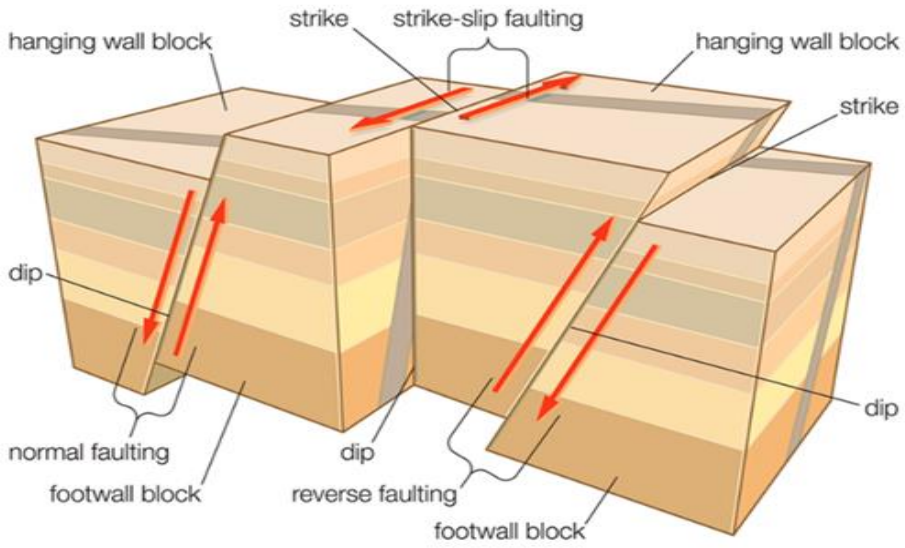


Fig. 2. Components of a Fault Rupture

1.1 Normal Fault:

A normal fault is one in which the rocks above the fault plane, or hanging wall block , move down relative to the rocks below the fault plane, or footwall block. Normal faults are common in areas undergoing extension or stretching. [2]

1.2 Reverse Fault:

A reverse fault is one in which the hanging wall block moves up relative to the footwall block. Reverse faults are common in areas undergoing compression or squeezing. [7]

1.3 Strike-slip fault:

When rocks on either side of a nearly vertical fault plane move horizontally, the movement is called strike-slip. Strike-slip faults are common in areas where there is significant lateral movement of the crust, such as along transform plate boundaries. [2]

1.4 Oblique-slip fault:

An oblique-slip fault is a combination of a normal or reverse fault and a strike-slip fault. The rocks on either side of the fault move both horizontally and vertically. [2]

2. **Research Methodology**

Three-dimensional numerical modelling was used to study the interactive mechanism of normal fault rupture with a 20-story building sitting on a raft or a pile foundation. ABACUS finite element software was used to carry out the numerical modelling.

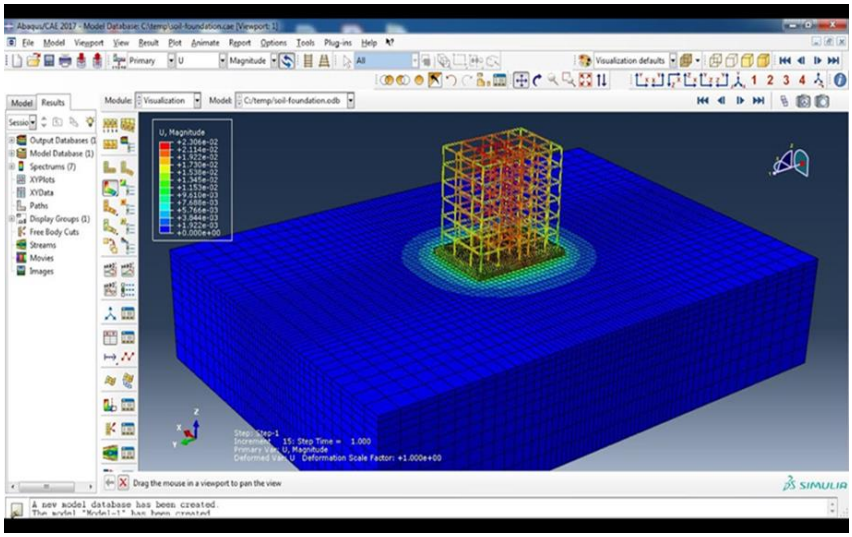


Fig. 3. Three-dimensional numerical modelling

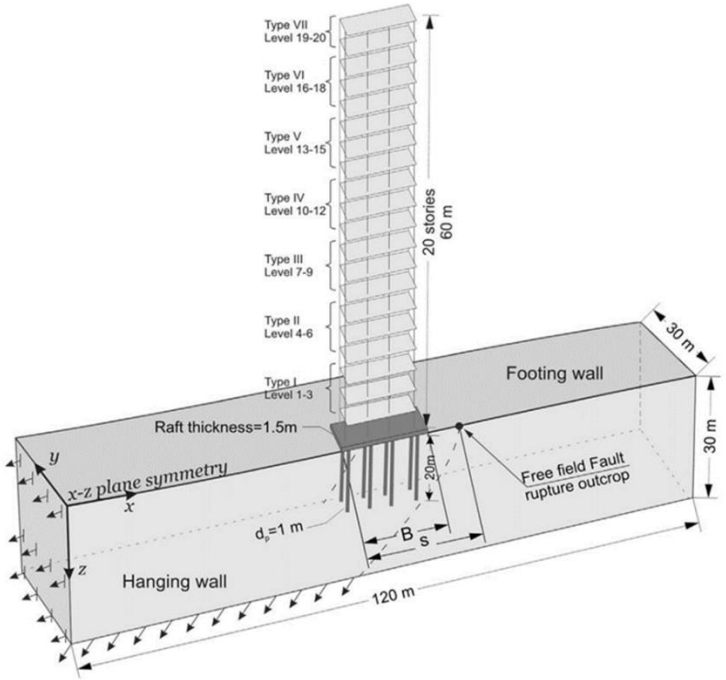


Fig. 4. A 20- storey high rise building of 60 m height is resting on the 4x4 piled raft. The thickness of the piled raft is 1 m, A 60 cm of fault slip was imposed at 60 degrees.

3. Model Analysis

Hypo plastic (clay) (by Mašín, 2005 model was used to capture soil behaviour. Piles and structural elements of the building was modelled as linear elastic material.

4. Results and Discussion

4.1 *Induced differential settlement of piled raft*

During the fault rupture in a raft foundation, as expected, piles are subjected to larger ground movement and stress-release than those which are farthest from the fault slip. As a result, differential settlement is induced in the piles. Fig. shows settlements of piled raft induced at various positions at different fault slip stages (i.e., = 0 cm, 5 cm, 15 cm, 20 cm up to 60 cm).

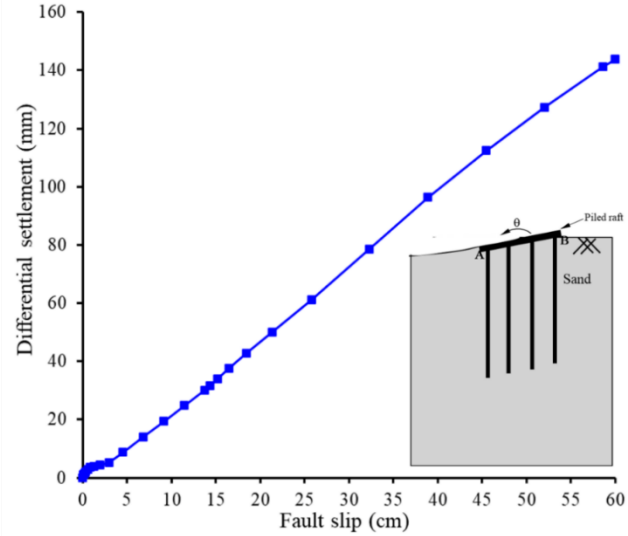


Fig. 5. Differential Settlement vs Fault Slip.

4.2 *Induced horizontal movement of piled raft*

It can be seen from the figure that horizontal movement is increased with the fault slip stages (i.e., = 0 cm, 5 cm, 15 cm, 20 cm up to 60 cm). It can be seen that, the movement occurred in the building was linear. Negligible horizontal movement was computed at the first stage of fault slip (i.e., 0 cm). However, as the fault slip continues, the horizontal movement was induced in the building. The maximum movement occurred at the fault slip 60 cm is about 400 mm.

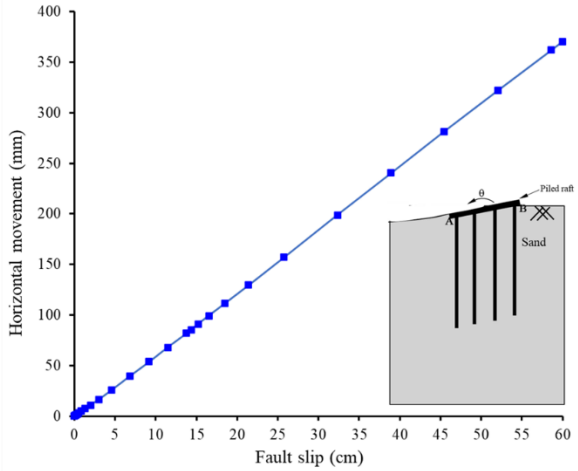


Fig. 6. Computed horizontal movement of the piled raft.

4.3 *Induced lateral deflection of the building*

Figure illustrates the induced lateral deflection of the building along each storey at different lateral deflections (i.e., = 5 cm, 10 cm, 20 cm, 40 cm and 60 cm). It can be seen from the figure that lateral deflection increased with height of the building. Negligible lateral deflection was computed at the first stage. However, as the fault slip continues, the substantial lateral deflection was induced in the building.

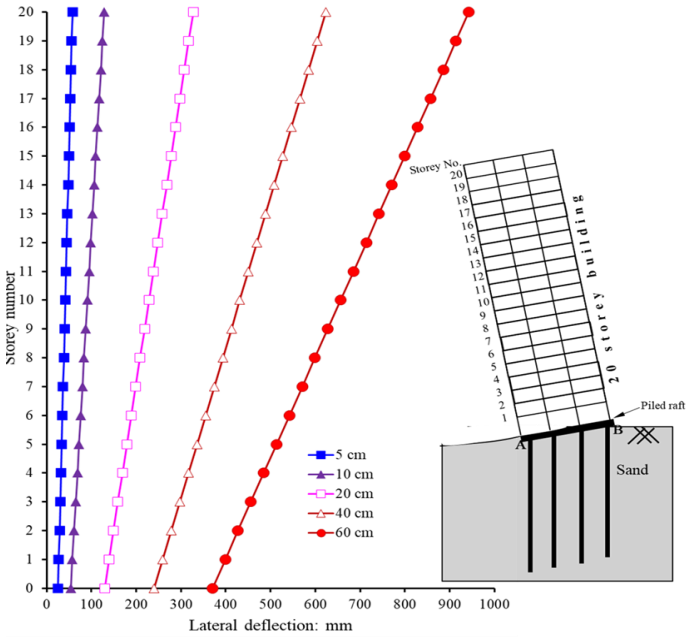


Fig. 7. Induced lateral deflection of the building.

4.4 *Permanent inter-story drift of building sitting on raft foundations*

Figure can clearly show the permanent inter-story drifts of the structure resting on raft foundations with a magnitude of (i.e., 5cm, 10cm, 20cm, 40cm & 60cm).

The inter-storey drift of the building can be defined as ratio of difference of deflections at two storeys to storey height.

Therefore, the inter-storey drift is 0.3% times greater at 60cm than 40cm with inter-storey drift of 0.06%.

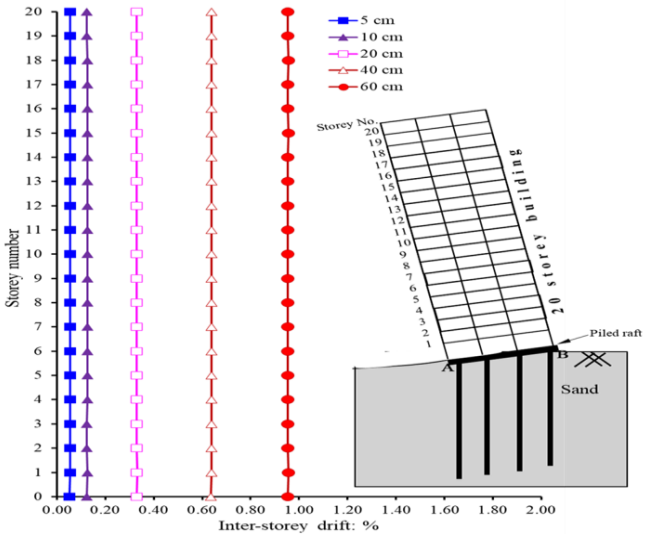


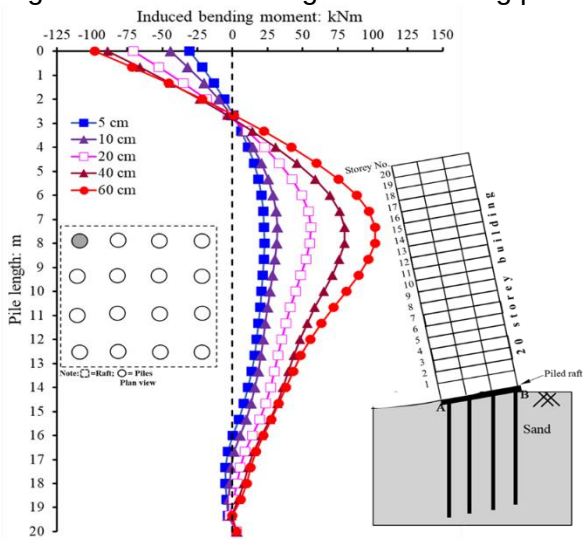
Fig. 8. Permanent inter-story drift.

4.5 *Structural response of pile (induced bending moment along piles)*

The maximum negative bending moment (100 kN-m) was predicted at head of pile P1.
To counterbalance the negative bending moment, positive bending moment was induced at lower portion of the pile.

Since the pile toes were free to move, negligible bending moment was induced at the toes of each pile.

Fig. 8. Induced bending moment along piles.



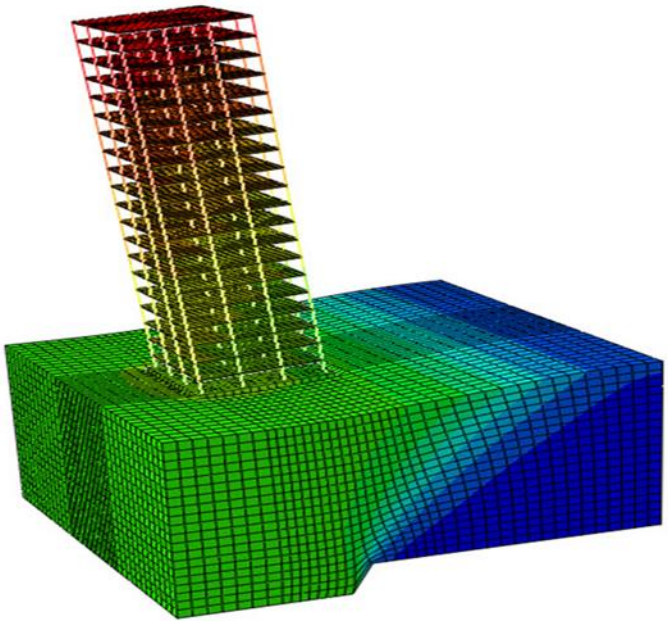


Fig. 9. Visualized deflected profile of the multi-storey building due to the fault rupture.

5. Conclusion

It was concluded that during the fault rupture in pile raft foundation, piles are subjected to larger ground movement. Consequently, differential settlement induced in the multi-story building. In addition to this, horizontal movement (Lateral movement) in the structure was noticed at different fault slip stages. Maximum negative bending moment was predicted at the head of pile P1. To counterbalance the negative bending moment, positive bending moment was induced at lower portion of the pile. It was observed that lateral deflection increased with the height of the building. Moreover, as the fault slip continues the substantial lateral deflection was induced in the building. Apart from this, the permanent inter-story drift of the building resting on pile raft foundation with different magnitudes was analysed. Consequently, the inter-story drift is 0.3% times greater at 60cm than 40cm with inter-story drift of 0.06%.

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Subject: Structural and Geotechnical Engineering

Theme: Sustainable and Resilient Structural Systems

Ref: 1st ICSIID//KHP/65

REVOLUTIONIZING SUSTAINABLE CONSTRUCTION: THE POTENTIAL OF MASS TIMBER

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ABSTRACT

Mass timber construction has gained significant recognition as an environmentally friendly alternative to conventional materials such as steel and reinforced concrete. This research examines the structural integrity, fire resistance, economic feasibility, seismic resilience, and ecological impact of mass timber, with a focus on cross-laminated timber (CLT) and glue-laminated timber (glulam). Findings indicate that while steel and reinforced concrete possess superior compressive and tensile strengths, mass timber exhibits an exceptional strength-to-weight ratio, which reduces overall structural loads. Seismic performance assessments demonstrate that timber structures dissipate seismic energy efficiently, particularly when integrated with hybrid construction techniques such as reinforced concrete cores or steel bracing. Fire resistance evaluations highlight that mass timber forms a protective char layer upon exposure to fire; however, additional fireproofing is required to comply with building safety regulations. Economic analysis reveals that CLT construction minimizes labor costs and shortens project completion time by up to 30%, though its initial material costs remain relatively high. A life cycle assessment (LCA) confirms that mass timber drastically reduces embodied carbon emissions, establishing it as a carbon-negative material when procured from sustainably managed forests. The study concludes that mass timber, especially when incorporated within hybrid construction systems, offers a structurally efficient, cost-effective, and sustainable solution for contemporary large-scale and high-rise developments. However, further improvements in fire protection strategies, regulatory frameworks, and industry adaptation are crucial to facilitating its broader implementation.

KEYWORDS: CLT, fire resistance, glulam, hybrid construction, mass timber, life cycle assessment, seismic resilience, sustainable materials.

15. Introduction

Timber has been a fundamental construction material throughout history, contributing to architectural advancements across various civilizations. Traditional timber structures, such as wooden houses, temples, and bridges, were widely used due to the abundance of forest resources. However, with the advent of reinforced concrete and steel, timber construction saw a decline, particularly in large-scale infrastructure and high-rise buildings. Concerns over its perceived lower strength, fire resistance, and durability contributed to its reduced use.

Recent advancements in engineered wood products (EWPs), including glue-laminated timber (glulam), laminated veneer lumber (LVL), and cross-laminated timber (CLT), have revived interest in timber construction. These materials offer enhanced strength, improved dimensional stability, and greater resistance to environmental factors. Among them, CLT has gained prominence, enabling multi-story timber buildings to be structurally viable.

The resurgence of mass timber construction is largely driven by sustainability initiatives. Unlike concrete and steel, which have high carbon footprints, timber is a renewable resource that sequesters carbon, reducing environmental impact. Many countries now incorporate performance-based building codes, allowing mass timber structures to meet modern safety and structural standards. Despite these benefits, challenges such as fire safety regulations, cost considerations, and public perception remain significant barriers to widespread adoption.

Hybrid construction, integrating timber with steel or reinforced concrete, offers a solution to these challenges by enhancing structural performance while maintaining sustainability benefits. This study evaluates mass timber's feasibility in modern construction, comparing its strength, cost efficiency, and environmental impact against conventional materials. By analyzing recent advancements and case studies, this research aims to provide insights into the future potential of mass timber in large-scale construction.

16. Materials and Methodology

2.1 Materials Used

This study focuses on mass timber construction, specifically analyzing the structural performance of cross-laminated timber (CLT) and glue-laminated timber (glulam). These materials were selected due to their increasing use in modern construction and their potential as sustainable alternatives to reinforced concrete and steel. The primary properties assessed include strength, fire resistance, seismic resilience, and cost efficiency.

2.2 Model Description

The study evaluates the mechanical behavior of mass timber elements under different loading conditions. The research is structured around three key parameters:

- **Structural Strength:** Compressive, tensile, and shear properties of CLT and glulam were compared to conventional materials.
- **Fire Resistance:** Fire performance was assessed by analyzing charring rates and protective layering techniques.
- **Seismic Behavior:** The ability of timber structures to dissipate seismic forces was studied, particularly in hybrid construction systems.

A comparative analysis was conducted to assess the feasibility of mass timber in high-rise and large-scale applications. Hybrid systems incorporating reinforced concrete cores and steel bracing were also evaluated.

2.3 Data Collection and Analysis

Experimental data were sourced from prior studies, industry standards, and case studies of existing mass timber structures. The study incorporated numerical simulations and life cycle assessments (LCA) to quantify carbon footprints and overall sustainability impacts. Fire resistance testing data were referenced from established codes, including ASTM E119 and BS EN 1365-1, to determine compliance with building safety regulations.

This methodology provides a comprehensive evaluation of mass timber construction, ensuring a balanced assessment of its structural, economic, and environmental viability in comparison to conventional materials.

17. Model Analysis

3.1 Equilibrium Analysis

To evaluate the stability and effectiveness of mass timber construction, structural equilibrium analysis was conducted. This involved assessing load-bearing capacity, lateral stability, and the impact of hybrid construction techniques on structural integrity. The equilibrium conditions of mass timber elements were determined by analyzing force distribution under different loading scenarios, including vertical and lateral loads.

3.2 Fire Resistance and Thermal Performance

Fire safety is a critical consideration in mass timber construction. Experimental studies have shown that CLT and glulam develop a protective char layer when exposed to fire, slowing combustion and maintaining structural integrity for a limited duration. However, additional fireproofing measures such as gypsum board encapsulation and fire-retardant coatings are necessary to meet building code requirements. Fire resistance ratings were analyzed in accordance with ASTM E119 and BS EN 1365-1 standards.

3.3 Seismic Performance Assessment

Mass timber structures exhibit favorable seismic performance due to their lightweight nature and flexible connections. Seismic response analysis indicated that timber buildings can effectively dissipate earthquake-induced energy, reducing structural damage. Hybrid systems incorporating reinforced concrete cores or steel bracing were found to enhance lateral stability, making them suitable for high-seismic regions.

3.4 Structural Efficiency in Hybrid Construction

Hybrid construction methods that combine mass timber with reinforced concrete or steel were analyzed to optimize both strength and sustainability. The integration of CLT floor panels with concrete cores enhances overall stiffness, while steel bracing improves lateral resistance. This approach mitigates some of the limitations of mass timber, making it viable for taller structures. The results of these analyses confirm that mass timber construction, particularly when used in hybrid systems, offers a structurally sound and environmentally friendly alternative to traditional materials. However, improvements in fire safety measures and regulatory adaptation are necessary for broader implementation.

18. Results and Discussion

18.1 Structural Performance Analysis

The mechanical properties of mass timber, reinforced concrete, and steel were analyzed to compare their structural efficiency. Table 1 presents the key mechanical properties of these materials. While concrete and steel provide higher compressive and tensile strengths, mass timber exhibits an excellent strength-to-weight ratio, reducing dead loads and improving structural efficiency.

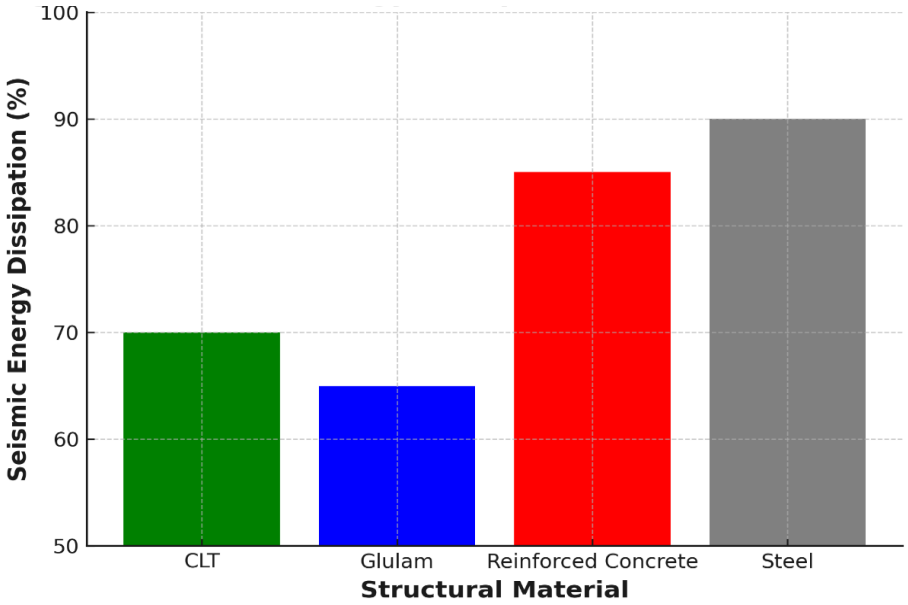
Table 1: Comparison of Mechanical Properties of Structural Materials

Property	CLT	Glulam	Reinforced Concrete	Steel
Density (kg/m³)	380-480	480-620	2300-2500	7750-7900
Compressive Strength (MPa)	28-45	33-50	32-42	255-390
Tensile Strength (MPa)	18-30	22-38	2.5-4.0	410-570
Elastic Modulus (GPa)	8.5-11	9.5-13	22-33	195-205
Shear Strength (MPa)	3.5-5.5	4.5-7.5	2.8-4.5	235-380

18.2 Seismic Performance Evaluation

Seismic testing revealed that mass timber structures dissipate energy effectively due to their lightweight nature and flexible connections. Hybrid systems incorporating steel bracing demonstrated improved lateral stability under dynamic loading. Figure 1 illustrates the seismic energy dissipation capacity of different materials.

Figure 1: Seismic Energy Dissipation of Structural Materials
(Graph showing seismic energy dissipation comparisons among CLT, Glulam, Reinforced Concrete, and Steel)



18.3 Fire Resistance Assessment

Mass timber forms a protective char layer when exposed to fire, delaying combustion. However, additional fire protection measures are required to meet building safety regulations. Table 2 outlines the fire resistance ratings of different materials.

Table 2: Fire Resistance Ratings of Structural Materials

Material	Fire Resistance (Minutes)	Char Rate (mm/min)
CLT (150 mm thick)	80-110	0.70-0.85
Glulam (200 mm thick)	100-160	0.65-0.80
Reinforced Concrete (200 mm thick)	190-250	N/A
Steel (unprotected)	25-40	N/A

18.4 Cost Efficiency and Construction Time

Economic analysis showed that while mass timber has higher initial material costs, it significantly reduces labor expenses and project timelines. Prefabrication plays a key role in cost-effectiveness. Table 3 compares construction costs and time for different materials.

Table 3: Cost Comparison of Structural Systems (Per Square Meter of Floor Area)

Cost Factor	CLT Construction (PKR)	Reinforced Concrete (PKR)	Steel Frame (PKR)

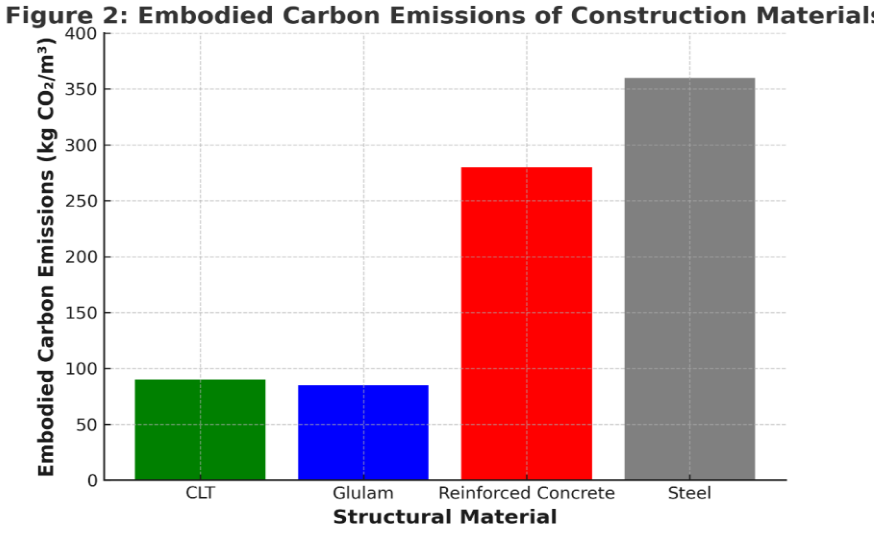
Material Cost	162,000 - 209,700	111,800 - 167,700	195,700 - 251,600
Labor Cost	50,400 - 83,900	83,900 - 111,800	69,900 - 97,800
Construction Time (Weeks)	8 - 12	12 - 16	10 - 14

18.5 Environmental Impact and Sustainability

Life cycle assessment (LCA) confirmed that mass timber has significantly lower embodied carbon emissions compared to concrete and steel. Figure 2 illustrates the embodied carbon emissions of various construction materials.

Figure 2: Embodied Carbon Emissions of Construction Materials (kg CO□ per m³)

(Graph comparing embodied carbon emissions of CLT, Glulam, Reinforced Concrete, and Steel)



18.6 Hybrid Construction as an Optimized Approach

Hybrid construction integrating mass timber with concrete or steel systems optimize structural performance, fire resistance, and cost efficiency. Table 4 presents a comparative analysis of different hybrid systems.

Table 4: Performance Comparison of Hybrid Structural Systems

System Type	Structural Efficiency	Fire Resistance	Seismic Performance	Cost-Effectiveness
CLT + Concrete Core	High	High	Moderate	Moderate
CLT + Steel Bracing	Moderate	Moderate	High	High

Concrete + Steel Hybrid	Very High	Very High	High	Moderate

The findings confirm that while mass timber offers substantial structural and environmental benefits, hybrid construction methods enhance its feasibility for high-rise and large-scale developments. Addressing fire safety challenges and optimizing regulatory frameworks will be crucial for its broader adoption.

19. Conclusion: This study evaluated the feasibility of mass timber construction by analyzing its structural performance, economic viability, fire resistance, seismic resilience, and environmental impact compared to conventional materials like reinforced concrete and steel. The findings indicate that mass timber (CLT and glulam) offers high strength-to-weight ratios, rapid construction time, and a lower carbon footprint. Structural analysis showed that while concrete and steel have higher compressive and tensile strengths, mass timber reduces dead loads and enhances seismic energy dissipation. Fire resistance studies confirmed that timber develops a protective char layer, but additional fireproofing is necessary for compliance with building codes. Cost analysis revealed that CLT construction lowers labor costs and project timelines by up to 30%, although higher initial material costs remain a challenge. Life cycle assessment (LCA) demonstrated that mass timber is carbon-negative, reducing the environmental footprint of buildings. Hybrid construction systems emerged as the optimal solution for large-scale and high-rise buildings, combining timber's sustainability with concrete or steel's structural reliability. However, regulatory barriers, fire safety concerns, and industry awareness must be addressed to accelerate mass timber adoption. Future research should focus on improving fire resistance techniques, developing enhanced connection systems for seismic stability, and expanding global regulatory frameworks to accommodate mass timber in high-rise construction. Expanding industry training programs and promoting hybrid construction strategies will further support the transition toward sustainable building practices

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Subject: Water Resource and Environmental Engineering

Theme: Wastewater Treatment and Reuse Technologies

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Sustainable Water Management: Wastewater Treatment and Reuse in Sukkur

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ABSTRACT:
This research explores the potential for wastewater reuse in the city of Sukkur, Pakistan, as a sustainable solution to the growing scarcity of freshwater resources. The study focuses on assessing the quality of domestic wastewater and evaluating its suitability for agricultural purposes after basic treatment. Samples were collected from selected drainage points in Sukkur and analyzed for key parameters such as pH, turbidity, total dissolved solids (TDS), electrical conductivity (EC), and biological oxygen demand (BOD). A cost-effective filtration unit was developed using locally sourced materials including gravel, sand, and charcoal. The treated water met acceptable standards for irrigation, showing notable reductions in pollutants. These findings highlight that with proper treatment, domestic wastewater can be safely reused for non-potable applications, which could significantly ease pressure on freshwater sources in water-stressed urban areas like Sukkur.

KEYWORDS: Wastewater reuse, Sukkur, irrigation, water quality, filtration system, sustainable water management, domestic wastewater

1. Introduction

Water scarcity is one of the most pressing challenges facing developing countries like Pakistan, where growing urban populations and agricultural demands are placing immense pressure on limited freshwater resources. Sukkur, a key city in Sindh province, is no exception. Located in a semi-arid region, Sukkur relies heavily on surface water from the Indus River and limited groundwater reserves, both of which are under increasing stress. As water demand rises and supply remains constrained, exploring alternative water sources has become critical for sustainable development. One promising solution is the reuse of treated domestic wastewater, particularly for non-potable applications such as irrigation. Wastewater is abundantly available in urban centers like Sukkur, yet much of it is discharged untreated into natural waterways, posing environmental and health risks. By reclaiming

and reusing this wastewater after appropriate treatment, it is possible to reduce the burden on freshwater systems, promote sustainable agriculture, and mitigate pollution. This research investigates the feasibility of wastewater reuse in Sukkur by analyzing the quality of untreated domestic wastewater and evaluating the effectiveness of a low-cost, locally assembled filtration system. The primary aim is to determine whether treated wastewater can safely be used for irrigation purposes in the region. Through laboratory testing and performance evaluation of the treatment unit, this study provides practical insights into how wastewater reuse can be integrated into local water management strategies. The motivation for this research stems from the urgent need to adopt resource-efficient and eco-friendly solutions in urban settings. By focusing on a city like Sukkur—where centralized wastewater treatment infrastructure is limited—this study highlights the potential of decentralized and community-level treatment systems. The findings are intended to guide policymakers, engineers, and local communities in developing affordable, effective, and environmentally responsible wastewater reuse practices.

2. Materials and Methodology

2.1 Study Area and Sampling Sites

The study was conducted in Sukkur, a major urban center in Sindh, Pakistan, situated along the Indus River. The city experiences a hot, semi-arid climate and is characterized by limited rainfall and high evapotranspiration rates. Wastewater from residential areas in Sukkur is typically discharged into open drains or canals without proper treatment, leading to potential environmental and health concerns. For this study, wastewater samples were collected from multiple drainage outlets in residential neighborhoods. The selected sites represented typical domestic wastewater sources without industrial contamination, allowing for a focused assessment of reuse potential for agricultural purposes.

2.1.1 Domestic Site

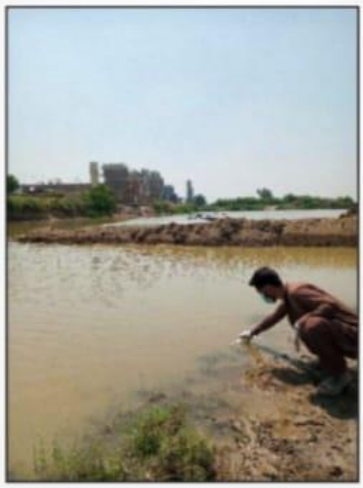
Qureshi Goth Nullah

2.1.2 Industrial Site

Site Area Nullah

2.1.3 Commercial Site

Clock Tower Sewage



1.1 Photograph of sample collection of Industrial wastewater

1.2 Photograph of sample collection of Domestic wastewater

1.3 Photograph of sample collection of Commercial wastewater

2.2 Sample Collection and Preservation

Wastewater samples were collected in clean, sterilized plastic bottles following standard procedures recommended by the American Public Health Association (APHA, 2017). Each sample was labeled with the collection date, time, and location. To ensure accurate testing, the samples were preserved at 4°C and transported to the laboratory on the same day.

2.3 Laboratory Analysis

2.1 Photograph while performing tests of wastewater samples

2.2 Photograph of COD finding instrument while analyzing COD of samples

2.3 Photograph while performing tests of wastewater samples

The samples were analyzed for the following key physicochemical parameters:

- **pH**
- **Turbidity**
- **Electrical Conductivity (EC)**
- **Total Dissolved Solids (TDS)**
- **Biological Oxygen Demand (BOD)**
- **Chemical Oxygen Demand (COD)**

Standard testing methods from the APHA and Pakistan Environmental Protection Agency (Pak-EPA) were used for each parameter. These parameters were selected to evaluate the wastewater's suitability for irrigation and to establish baseline values for comparison with treated samples.

2.4 Filtration Unit Design

A simple, gravity-fed filtration unit was constructed using locally available materials. The unit consisted of a cylindrical container layered with:

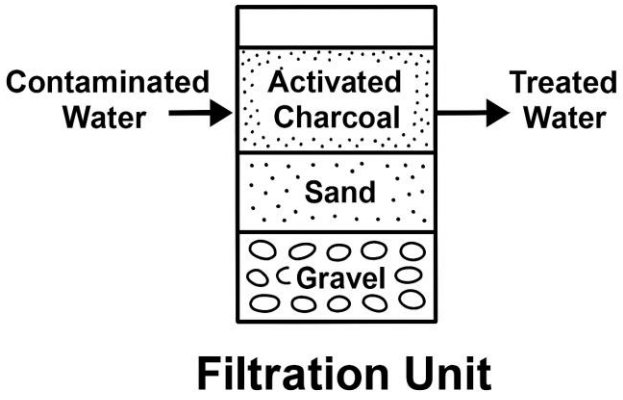


Figure 1

- **Gravel (bottom layer)** – for supporting the weight of the upper layers and removing coarse particles.
- **Fine Sand (middle layer)** – to trap smaller suspended solids.
- **Activated Charcoal (top layer)** – to reduce odor, color, and organic pollutants.

This multi-layered setup was designed for low-cost and low-maintenance treatment, making it suitable for household or community-level use in urban neighborhoods of Sukkur.

2.5 Treatment and Post-Treatment Analysis

Untreated wastewater samples were passed through the filtration system, and the treated water was collected for post-treatment analysis. The same parameters tested in the raw samples were re-evaluated to assess the treatment efficiency of the filtration unit.+

2.6 Data Analysis

The performance of the treatment system was assessed by calculating the percentage reduction in each parameter. Descriptive statistics were used to interpret the results, and the treated water quality was compared with irrigation standards set by FAO and Pak-EPA to determine its reuse potential.

3. Results and Discussion

3.1 Physicochemical Characteristics of Untreated Wastewater

Initial analysis of the collected wastewater samples revealed that several parameters exceeded acceptable limits for direct agricultural use. The pH values ranged from 7.3 to 8.1, which falls within a tolerable range for most crops. However, other indicators like Turbidity, TDS, EC, BOD, and COD were significantly higher than recommended standards.

Table 1. Physicochemical Characteristics of Untreated Wastewater

Parameter	Observed Range	FAO Limit for Irrigation	Remarks
pH	7.3 – 8.1	6.5 – 8.4	Within acceptable range
Turbidity (NTU)	42 – 58	< 5	Exceeds limit
EC (mS/cm)	2.1 – 2.6	≤ 1.5	High salinity risk
TDS (mg/L)	1300 – 1650	≤ 1000	Above acceptable level
BOD (mg/L)	150 – 190	≤ 100	Excessive organic content
COD (mg/L)	300 – 350	≤ 250	Exceeds recommended limit

- **Turbidity** was observed between 42–58 NTU, indicating high levels of suspended solids.
- **Electrical Conductivity (EC)** values ranged from 2.1 to 2.6 mS/cm, exceeding thresholds for irrigation in some sensitive soils.
- **TDS** ranged from 1300–1650 mg/L, suggesting salinity issues if applied directly over time.
- **BOD** and **COD** values were also elevated, with BOD around 150–190 mg/L and COD above 300 mg/L, indicating a substantial organic load.

These results confirm that untreated domestic wastewater in Sukkur is not suitable for direct reuse in agriculture and requires treatment to meet safety and quality standards.

3.2 Performance of the Filtration System: After passing through the filtration unit, the wastewater showed considerable improvement in quality:

Table 2: Comparison of Key Parameters Before and After Treatment

Parameter	Untreated Value	Average Value After Treatment	Treated Value	Percentage Reduction
pH	7.3 – 8.1	7.5	Remained stable (7.4 – 8.0)	~85%
Turbidity (NTU)	42 – 58	1.8	<10 NTU	~20%
Electrical Conductivity (mS/cm)	2.1 – 2.6	1100	Reduced proportionally (approx. 1.6 – 2.0)	~30%
Total Dissolved Solids (mg/L)	1300 – 1650	38	~1050 – 1125 mg/L	~75%
BOD (mg/L)	150 – 190	120	<40 mg/L	~65%
COD (mg/L)	>300		~120 mg/L	~85%

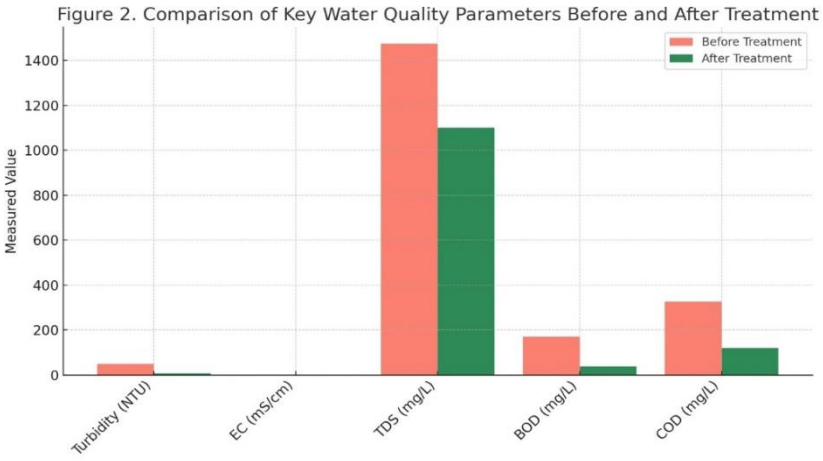


Figure 2

- **Turbidity** was reduced by over 80%, bringing values within acceptable ranges.
- **TDS** showed a reduction of approximately 25–30%, and **EC** dropped proportionally.
- **BOD** levels decreased to below 40 mg/L, and **COD** dropped to around 120 mg/L—well within acceptable thresholds for irrigation use.

The pH remained stable, and no significant changes in color or odor were observed in the treated water. These findings suggest that the gravel-sand-charcoal filter effectively removes suspended particles and a significant portion of organic contaminants.

3.3 Suitability for Irrigation Use

Based on FAO and Pak-EPA irrigation standards, the treated wastewater falls within the safe range for reuse in agricultural fields, especially for non-edible crops or ornamental plants. While long-term usage may still require periodic monitoring (particularly for TDS and salinity), the treated water is safe for controlled reuse, reducing reliance on freshwater sources.

3.4 Socio-Environmental Impact and Feasibility

The use of locally available materials and the simple design of the filtration unit make it highly feasible for replication in other areas of Sukkur or similar urban settlements. It requires minimal maintenance, no electricity, and can be deployed at the household or community level.

This approach not only offers an environmentally friendly alternative to conventional wastewater disposal but also promotes sustainable water resource management. In water-stressed regions like Sukkur, decentralized wastewater reuse systems could play a key role in mitigating future water shortages while improving hygiene and reducing environmental pollution.

4. Conclusion

The findings of this study clearly demonstrate the potential of domestic wastewater reuse as a sustainable water management strategy for the city of Sukkur. Laboratory analyses confirmed that untreated wastewater from residential sources contains elevated levels of turbidity, dissolved solids, and organic contaminants, making it unsuitable for direct agricultural use. However, with basic yet effective treatment using a low-cost filtration system composed of gravel, sand, and charcoal, significant improvements in water quality were achieved.

Post-treatment water parameters met or closely approached the standards set by FAO and Pak-EPA for irrigation. The system proved to be efficient in reducing turbidity, BOD, and COD while being simple to construct and operate with locally available materials. This makes it a viable option for small communities, households, or decentralized urban sectors that lack access to centralized wastewater treatment infrastructure.

The implementation of such community-level solutions in Sukkur could reduce the burden on freshwater resources, improve sanitation, and promote sustainable agriculture. These findings highlight the need for increased awareness, supportive policy frameworks, and collaborative efforts between local authorities, researchers, and the public to encourage safe and practical wastewater reuse.

Future research could further enhance this work by testing advanced media combinations, exploring disinfection methods, and conducting long-term monitoring of soil and crop health using treated wastewater. The insights from this study contribute toward sustainable water reuse initiatives not only in Sukkur but in other semi-arid urban regions facing similar water stress.

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Subject: Transportation and Infrastructure Engineering

Theme: Pavement Design, Maintenance, and Sustainability

Ref: 1st ICSIID//KHP/67

AN EXPERIMENTAL STUDY ON THE MECHANICAL PROPERTIES OF HUMAN HAIR FIBRE REINFORCED CONCRETE FOR SUSTAINABLE PAVEMENT APPLICATIONS

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ABSTRACT

The increasing demand for sustainable and cost-effective construction materials has led to innovative approaches in concrete reinforcement. This study investigates the impact of human hair fibre as a reinforcement material in concrete pavements, focusing on variations in mechanical properties such as compressive strength, flexural strength, skid resistance, and workability. Human hair, an abundant and biodegradable waste material, possesses high tensile strength comparable to that of copper wire of similar diameter. Its integration into concrete provides potential benefits in enhancing structural integrity while addressing environmental concerns associated with waste disposal. The research involved experimental testing of concrete specimens with different percentages of human hair fibre reinforcement, ranging from 0% to 3% by weight of cement. The findings indicate that the addition of hair fibres up to a certain threshold improves the flexural and compressive strength of concrete while enhancing skid resistance. However, excessive fibre content reduces workability and introduces challenges in uniform mixing. This study underscores the viability of human hair as an eco-friendly and cost-efficient reinforcement alternative in concrete pavement construction, contributing to sustainable engineering practices.

KEYWORDS: Cost-effective pavement, Eco-friendly materials, Human hair fibre, Mechanical properties, Reinforced concrete, Sustainable construction, Skid resistance.

1. Introduction

Concrete remains one of the most extensively utilized construction materials due to its durability,

adaptability, and high compressive strength. Despite these advantages, conventional concrete exhibits low tensile strength and a tendency to crack under tensile stress. To counteract these weaknesses, reinforcement techniques such as steel bars and fibre incorporation have been widely adopted to enhance mechanical properties. With increasing emphasis on sustainability and cost efficiency in construction, researchers have explored alternative reinforcement materials derived from natural or waste sources. Human hair, a biodegradable waste material that is abundantly available, is typically discarded as waste. Due to its impressive tensile strength—comparable to that of copper wire of the same diameter—it presents a compelling case for use as a reinforcing agent in concrete. Historically, fibres such as straw, horsehair, and asbestos were incorporated into construction materials to enhance their properties. Modern fibre-reinforced concrete (FRC) has advanced significantly, with synthetic fibres like polypropylene, glass, and steel fibres being widely used to improve tensile strength, ductility, and crack resistance. However, the production of synthetic fibres is energy-intensive and relies on non-renewable resources, raising sustainability concerns. In contrast, natural fibres such as coconut coir, jute, and animal hair provide cost-effective and environmentally friendly reinforcement alternatives. Among these, human hair offers unique advantages due to its lightweight composition, high tensile strength, and ease of integration into concrete mixtures. The potential benefits of using human hair fibre in concrete include improved crack resistance, increased flexural strength, and enhanced skid resistance in pavement applications. Additionally, repurposing human hair as a reinforcement material provides a sustainable solution to waste management while reducing reliance on conventional reinforcement materials. However, challenges such as reduced workability, fibre dispersion issues, and long-term durability need to be addressed through optimized mix designs and processing techniques. This research investigates the feasibility of utilizing human hair fibres in concrete pavements to enhance mechanical properties while supporting sustainability initiatives. The study aims to identify the optimal fibre percentage that maximizes improvements in compressive strength, flexural strength, skid resistance, and workability, while addressing challenges related to mixing and durability. By assessing human hair as a potential reinforcement material, this research contributes to the development of sustainable and cost-efficient construction solutions. Furthermore, it explores how hair fibres interact with the cement matrix, their bonding mechanisms, and the long-term structural behavior of human hair fibre-reinforced concrete (HHFRC).

2. Materials and Methodology

2.1 Materials Used

The materials used in this study were carefully selected to ensure consistency and reliability in the preparation of human hair fibre-reinforced concrete (HHFRC). Ordinary Portland Cement (OPC) conforming to ASTM C150 standards was utilized as the primary binding material. The fine aggregate consisted of natural sand, which was sieved to remove impurities and ensure proper grading. Crushed stone with a maximum size of 25 mm was used as the coarse aggregate, and it was thoroughly washed

and conditioned to a saturated surface dry (SSD) state to prevent additional water absorption during mixing. Potable water was used in the concrete mix with a water-cement ratio of 0.6 to ensure adequate hydration of the cement. The human hair fibres, sourced from local barber shops, underwent a meticulous cleaning process, which included manual removal of dirt, multiple washes with shampoo and antiseptic solution, and cutting to an average length of 1 inch. This preparation

ensured uniform distribution of the fibres within the concrete mix.

2.2 Mix Proportion and Preparation

A standard concrete mix ratio of 1:2:4 (cement:sand:coarse aggregate) was used. Human hair fibres were incorporated into the dry mix at varying percentages (0%, 0.125%, 0.25%, 0.5%, 1%, and 3% by weight of cement) before the incremental addition of water. The mixing process was performed in a mechanical mixer to achieve a homogeneous blend. The prepared concrete was cast into standard cube moulds (15 cm × 15 cm × 15 cm) for compressive strength testing, beam moulds (100 mm × 100 mm × 500 mm) for flexural strength testing, and slab moulds for skid resistance evaluation. The moulds were filled in layers, with each layer compacted using a vibrating table to eliminate air voids and enhance fibre distribution.

2.3 Curing Process

After 24 hours, the specimens were demoulded and immersed in water tanks for curing. The curing periods were set at 7, 14, and 28 days, with regular water changes to maintain optimal conditions. This process ensured complete hydration and allowed for proper strength development.

2.4 Testing Procedures

- **Workability Test:** A slump test (ASTM C143) was conducted to assess the workability of the fresh concrete mix.
- **Compressive Strength Test:** The cubes were subjected to a compression testing machine, with the ultimate load recorded to determine the compressive strength.
- **Flexural Strength Test:** The center-point loading method (ASTM C293) was used to evaluate the flexural strength of the beam specimens.
- **Skid Resistance Test:** A pendulum skid resistance tester (BSI, 1990) was employed to measure skid resistance on dry and wet surfaces.

The collected data were statistically analyzed to determine the optimal human hair fibre percentage that enhances concrete performance while mitigating its drawbacks.

3. Model Analysis

The analysis of human hair fibre-reinforced concrete (HHFRC) was conducted by evaluating its mechanical properties based on the experimental data collected. This section discusses the effects of varying hair fibre content on workability, compressive strength, flexural strength, and skid resistance. The model analysis is structured to highlight trends observed in the performance of HHFRC and identify the optimal fibre content for improving pavement construction.

3.1 *Workability Analysis*

The workability of concrete was assessed using the slump test, which measures the ease of handling and placement. The results indicated that as the hair fibre content increased, the slump value decreased, suggesting a reduction in workability. The presence of fibres interfered with the flow of the concrete mix, causing difficulties in mixing and compaction. At 0.25% hair content, a slight reduction in workability was observed but remained within acceptable limits. However, beyond 1% fibre content, workability was significantly compromised, necessitating adjustments in water content or the use of plasticizers to improve mix performance.

3.2 *Compressive Strength Analysis*

The compressive strength of HHFRC was determined through cube tests at 7, 14, and 28 days of curing. The results revealed that incorporating human hair fibres initially enhanced compressive strength, reaching an optimal value at 0.25% fibre content. Beyond this percentage, strength began to decline due to improper fibre dispersion and the formation of weak zones within the concrete matrix. The highest recorded compressive strength was approximately 15% greater than plain concrete at 0.25% fibre content, demonstrating that a controlled amount of hair fibres can contribute to load-bearing capacity. However, at 3% fibre content, compressive strength dropped by nearly 28%, indicating that excessive fibre addition disrupts the uniformity and structural integrity of the concrete.

3.3 Flexural Strength Analysis

Flexural strength testing was performed using beam specimens under center-point loading. The results showed a significant improvement in flexural capacity with the addition of human hair fibres. At 0.25% fibre content, the flexural strength increased by approximately 43% compared to plain concrete, highlighting the ability of hair fibres to bridge microcracks and delay failure under bending loads. However, as fibre content exceeded 1%, flexural strength decreased due to clustering effects, which reduced the effective stress distribution across the matrix. The results suggest that human hair fibres can be beneficial for applications requiring improved tensile performance, particularly in pavement construction where crack resistance is essential.

3.4 Skid Resistance Analysis

The skid resistance of HHFRC pavement specimens was evaluated under both dry and wet conditions. The results indicated a progressive increase in skid resistance with higher fibre content, attributed to the increased surface roughness provided by the exposed hair fibres. At 3% fibre content, the skid resistance value (SRV) improved by approximately 47% in dry conditions and 42% in wet conditions compared to plain concrete.

These findings demonstrate that HHFRC can enhance the safety of pavement surfaces by providing better traction, reducing the risk of skidding in both dry and wet environments. However, an optimal balance must be maintained to prevent excessive surface irregularities that could compromise durability.

3.5 Optimal Fiber Content Determination

Based on the model analysis, the ideal hair fibre content for reinforcement in concrete pavements lies within the range of 0.25% to 0.5% by weight of cement. This range achieves a balance between improved mechanical performance and acceptable workability. Excessive fibre content negatively affects workability and compressive strength while offering only marginal improvements in flexural capacity and skid resistance. Therefore, maintaining fibre dosage within the recommended range ensures optimal performance and durability of HHFRC in pavement applications.

4. Results and Discussion

4.1 Effect of Hair Fiber on Workability

The slump test results demonstrated that increasing human hair fibre content led to a progressive reduction in workability. The reference concrete mix without hair fibres exhibited the highest slump value, indicating good flowability. As fibre content increased to 0.25%, the slump value remained within acceptable limits, but further increases to 1% and 3% significantly reduced workability.

The reduction in slump can be attributed to the high surface area of the fibres, which absorbed more mixing water and created interlocking effects that restricted flow. While workability challenges could be addressed through the use of plasticizers, careful proportioning of fibre content is essential to maintain a balance between mechanical performance and ease of placement.

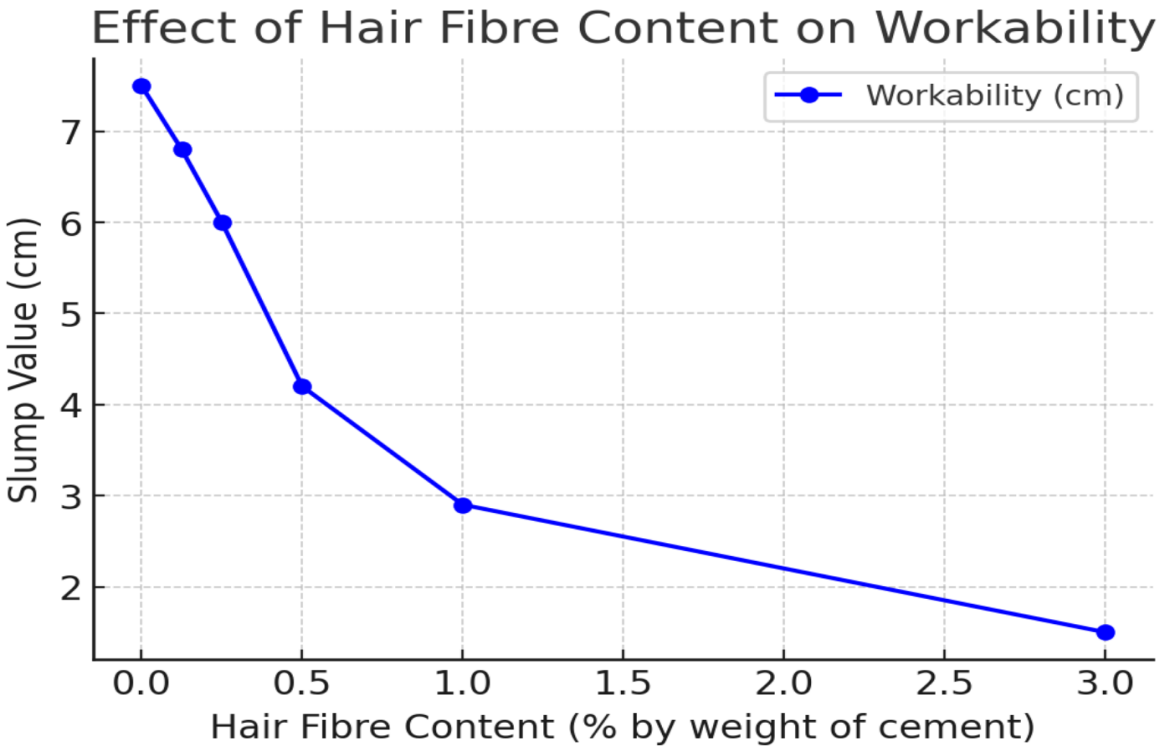

FIGURE 1: EFFECT OF HAIR FIBRE ON WORKABILITY OF CONCRETE

4.2 Effect of Hair Fiber on Compressive Strength

Compressive strength tests at 7, 14, and 28 days revealed that human hair fibre reinforcement initially enhanced strength at lower fibre percentages. The highest compressive strength was recorded at 0.25% hair fibre content, showing an increase of approximately 15% compared to plain concrete.

This improvement is attributed to the bridging effect of fibres, which enhanced load transfer and delayed crack propagation. However, at higher fibre content (1% and 3%), compressive strength declined, with a reduction of nearly 28% at 3% fibre content.

The decrease in strength is associated with improper fibre dispersion, weak bonding between fibres and the cement matrix, and increased void content within the concrete mix.

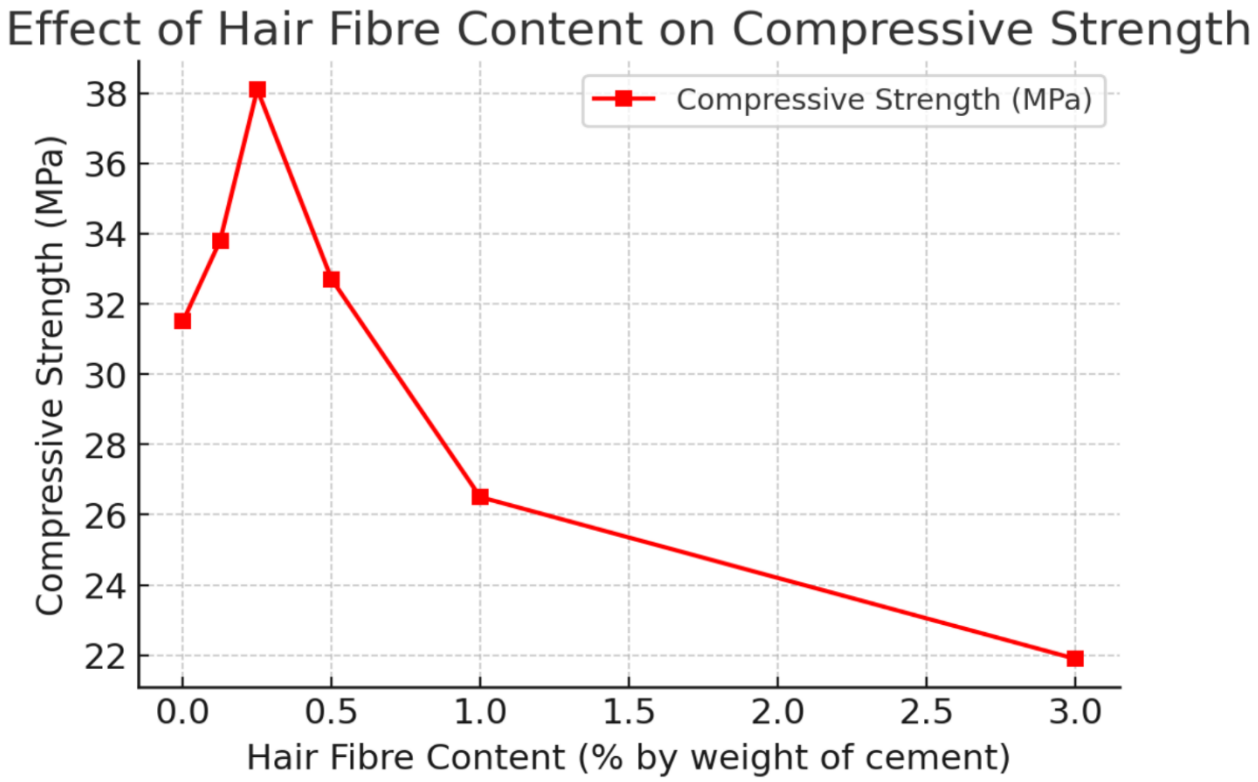

FIGURE 2: EFFECT OF HAIR FIBRE ON COMPRESSIVE STRENGTH OF CONCRETE

4.3 Effect of Hair Fiber on Flexural Strength

Flexural strength tests indicated that human hair fibres significantly improved the bending resistance of concrete. At 0.25% fibre content, flexural strength increased by 43% compared to control samples.

This enhancement is attributed to the ability of hair fibres to arrest crack propagation and improve ductility under flexural loading.

However, beyond 0.5% fibre content, flexural strength began to decrease due to fibre clumping, which led to non-uniform stress distribution. The findings suggest that human hair fibre reinforcement is most effective for flexural strength enhancement at moderate dosage levels.

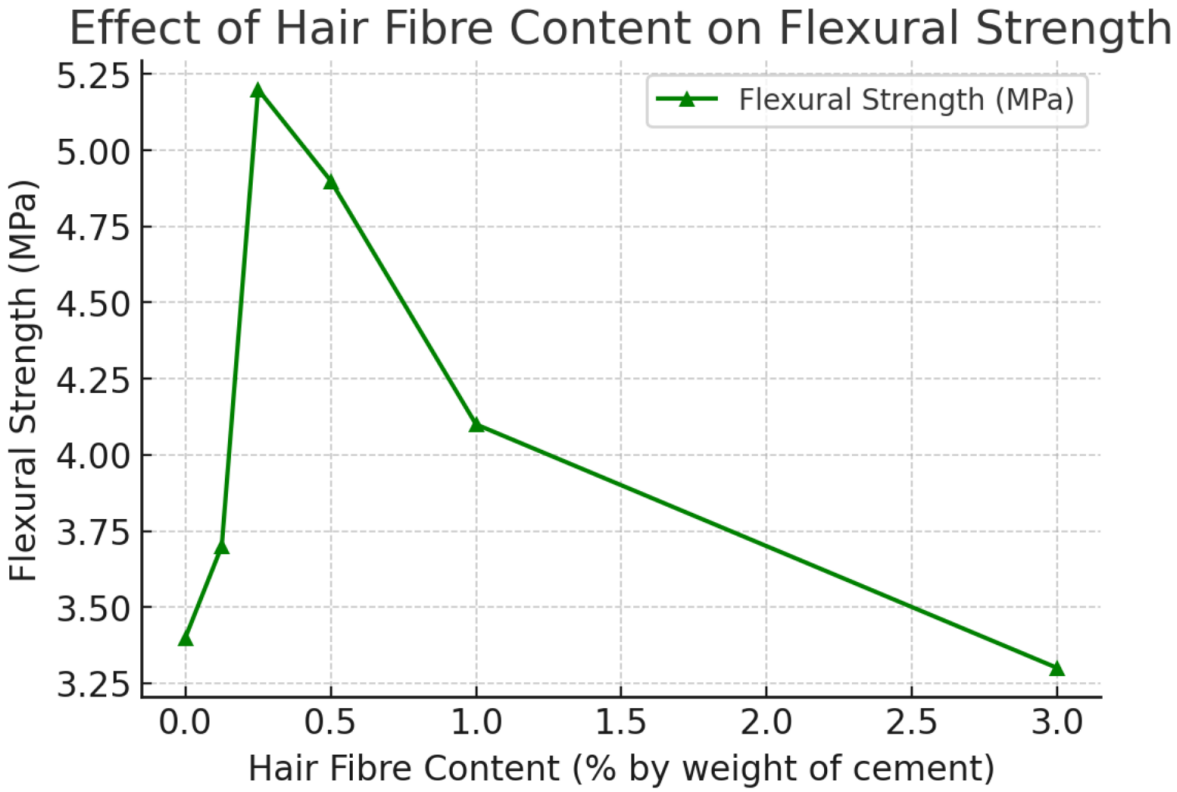

FIGURE 3: EFFECT OF HAIR FIBRE ON FLEXURE STRENGTH OF CONCRETE

4.4 Effect of Hair Fiber on Skid Resistance

Skid resistance tests demonstrated a clear improvement in surface friction with increasing fibre content. At 3% hair fibre content, skid resistance increased by 47% under dry conditions and 42% under wet conditions.

The improvement in skid resistance is attributed to the rougher surface texture created by exposed fibres, which provided enhanced traction.
This finding is particularly relevant for pavement applications where slip resistance is a critical factor in ensuring safety.

However, excessive surface roughness may lead to premature wear, emphasizing the need for optimizing fibre dosage.

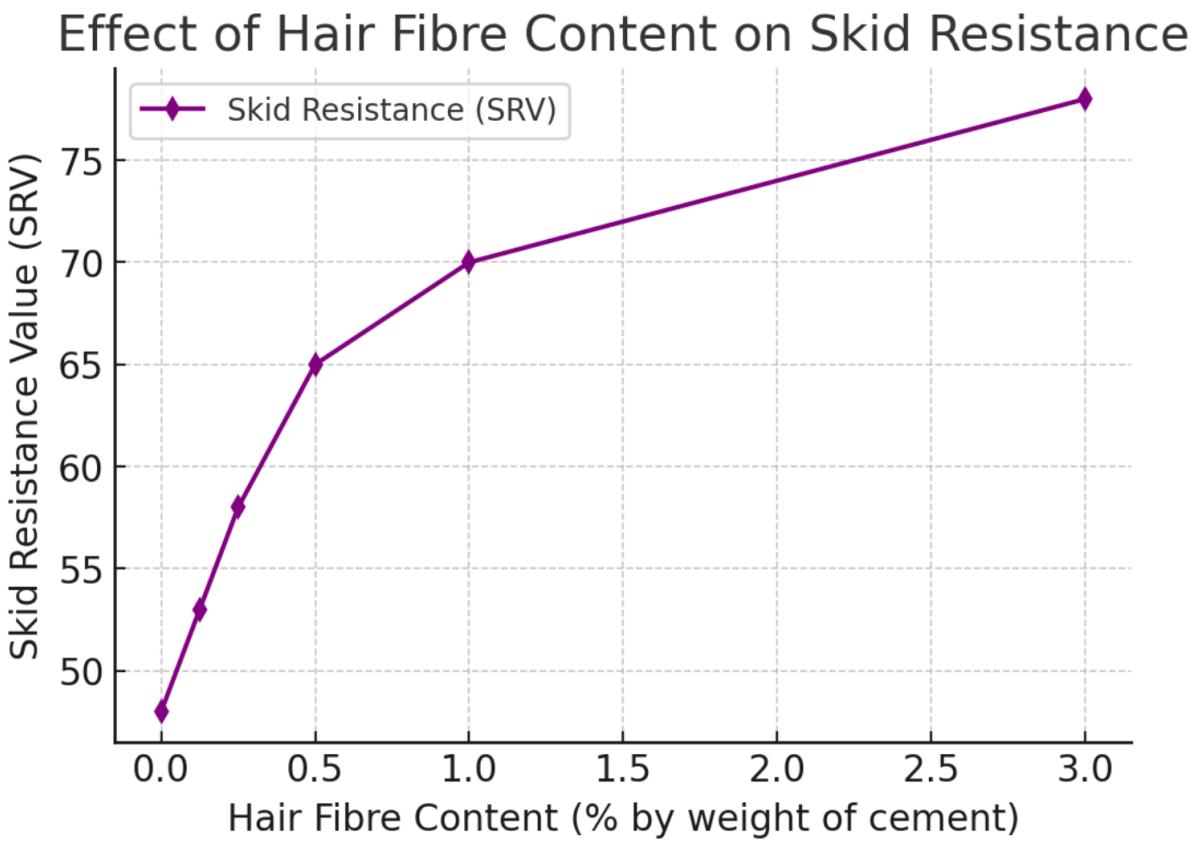

FIGURE 4: EFFECT OF HAIR FIBRE ON SKID RESISTANCE OF WET CONCRETE PAVEMENT SURFACE

4.5 Summary of Findings

The results confirm that human hair fibre reinforcement offers notable benefits in terms of flexural strength and skid resistance while presenting challenges in workability and compressive strength at higher fibre content.

The optimal fibre dosage range for balanced performance was identified as 0.25% to 0.5% by weight of cement.

Further research is recommended to explore methods for improving workability and ensuring uniform fibre dispersion in the concrete matrix.

5. Conclusion

This study demonstrated the potential of human hair fibres as a sustainable and cost-effective reinforcement material for concrete pavement applications. The experimental findings confirmed that

incorporating hair fibres enhances flexural strength and skid resistance while influencing compressive strength and workability.

The optimal fibre content was determined to be between 0.25% and 0.5% by weight of cement, ensuring a balance between performance benefits and practical feasibility. While HHFRC presents a viable alternative for sustainable construction, further research is needed to address long-term durability, fibre dispersion challenges, and potential enhancements through hybrid reinforcement approaches.

By repurposing human hair waste in construction, this study contributes to eco-friendly engineering solutions and circular economy principles.

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Subject: Water Resource and Environmental Engineering

Theme: Environmental Impact Assessment and Sustainable Planning

Ref: 1st ICSIID//KHP/68

IMPACT OF RISING SEA LEVELS ON THE INDUS DELTA: INFRASTRUCTURE AND MITIGATION STRATEGIES

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ABSTRACT:

This paper presents a comprehensive analysis of the impacts of rising sea levels on the Indus Delta—an ecologically and economically critical region in Pakistan. Accelerated sea-level rise, driven by global climate change and exacerbated by regional factors such as reduced sediment supply and land subsidence, poses significant risks to coastal infrastructure and agricultural productivity. Using a blend of theoretical framework and numerical simulations executed in MATLAB and GIS, this study examines coastal erosion, saltwater intrusion, and the degradation of built infrastructure. In addition, the paper evaluates an array of mitigation and adaptation strategies, ranging from engineered coastal defenses to nature-based solutions like mangrove restoration. Our results indicate that critical urban areas, including parts of Thatta and Badin, and agricultural zones in rural Sindh, face severe risks. These findings underscore the urgency for coordinated, multi-level interventions to protect the delta's infrastructure and communities and to guide sustainable coastal management practices (IPCC, 2021; WWF Pakistan, 2019).

KEYWORDS: Coastal defenses, coastal erosion, Indus Delta, mitigation strategies, sea-level rise, infrastructure resilience

1. Introduction

The Indus Delta, situated along Pakistan's southern coastline, is one of the country's most vital and dynamic ecosystems. It supports a diverse range of flora and fauna, and underpins critical human activities such as agriculture, fisheries, and transportation. Over recent decades, the region has been facing unprecedented challenges due to accelerated sea-level rise—a consequence of global climate change. This phenomenon is compounded by regional issues including diminished sediment deposition, largely owing to upstream damming and water diversion, and land subsidence. Together, these factors have accelerated coastal erosion, increased saltwater intrusion, and led to the submergence of fertile lands. In this paper, we provide a detailed investigation into how rising sea

levels are altering the physical landscape and affecting the socio-economic fabric of the Indus Delta. Our extended discussion in the Introduction emphasizes the importance of this research. Not only does the delta serve as an essential source of livelihood for millions, but it also plays a crucial role in maintaining ecological balance and biodiversity. The accelerated erosion and degradation of infrastructure—such as roads, bridges, and urban centers—have serious implications for both local economies and regional development. Affected areas include urban localities like Thatta and Badin, as well as several rural agricultural communities where saltwater intrusion is gradually diminishing arable land. This study is motivated by the need to address these escalating challenges through a systematic investigation. By integrating historical data, simulation models, and scenario analysis, we aim to forecast the future conditions of the delta under varying levels of sea-level rise. Our objective is to identify effective and sustainable mitigation strategies that not only protect the built environment but also support the resilience of natural ecosystems. Furthermore, we discuss the implications of our findings for policy planning and adaptive management at both local and regional levels. Through this work, we hope to contribute valuable insights that can facilitate informed decision-making and proactive intervention measures, thereby enhancing the long-term sustainability of the Indus Delta (Khan & Hussain, 2020; Rahman & Akter, 2022).

2. Materials and Methodology

2.1 Data Collection

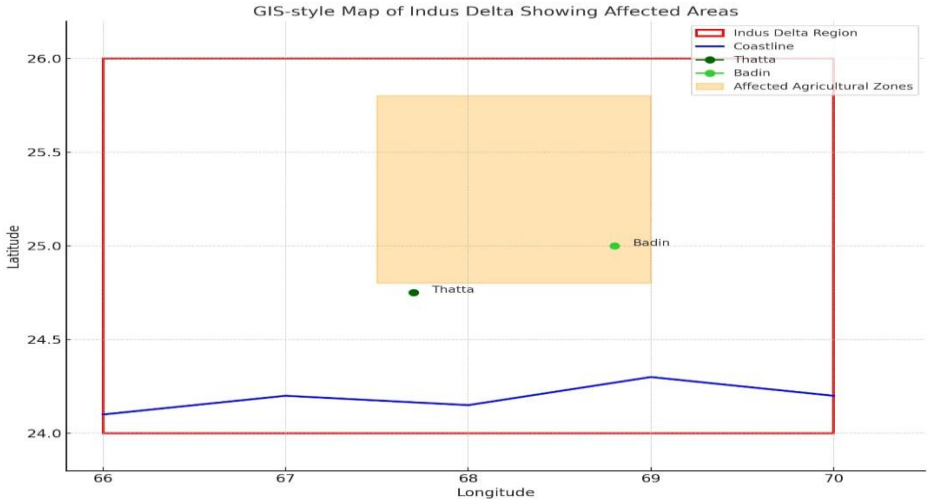
The foundation of this research rests on an extensive array of secondary data sources:

- **Climatological Reports:** We used the latest sea-level rise projections from the IPCC (2021).
- **Governmental and Institutional Databases:** Data related to local infrastructure, land-use patterns, and coastal erosion rates were obtained from various Pakistani environmental agencies.
- **Academic Literature and Case Studies:** Peer-reviewed research articles provided insights on coastal defense mechanisms and nature-based adaptation strategies (WWF Pakistan, 2019; Khan & Hussain, 2020).

2.2 Theoretical Framework and Simulation Model: A conceptual framework was developed to simulate the interactions among rising sea levels, coastal erosion, and infrastructure degradation in the Indus Delta. The simulation model includes:

- **Sea-Level Metrics:** Incorporating both historical trends and future projections.
- **Erosion Dynamics:** Evaluating the rate of coastline recession under scenarios with varying sediment supply and tidal conditions.
- **Infrastructure Vulnerability:** Assessing risk factors for critical infrastructures such as roads, bridges, and urban settlements in affected areas like Thatta and Badin.
- **Mitigation Strategies**: Simulating the efficacy of various adaptation measures including both engineered structures and nature-based solutions.

The simulation was implemented using MATLAB, while GIS tools were employed to spatially map the results. For detailed definitions of the model variables and parameters, please refer to Tables 1 and 2 below.



2.3 Variable and Parameter Definition

Table 1. Model Variables Used

Variable	Definition
S	Coastal areas susceptible to erosion
I	Areas currently experiencing infrastructure impact
R	Resilient or recovered coastal regions (post-mitigation)
N	Total coastal region area

Table 2. Model Parameters Used

Parameter	Definition
δ (delta)	Natural erosion rate
ρ (rho)	Rate of sediment deposition (or reduction)
β (beta)	Impact factor on infrastructure

γ (gamma)	Mitigation (recovery) rate
μ (mu)	Rate of loss due to flooding/inundation

A schematic diagram (Fig. 1) of the model flow represents the dynamic transitions among vulnerable, impacted, and resilient regions.

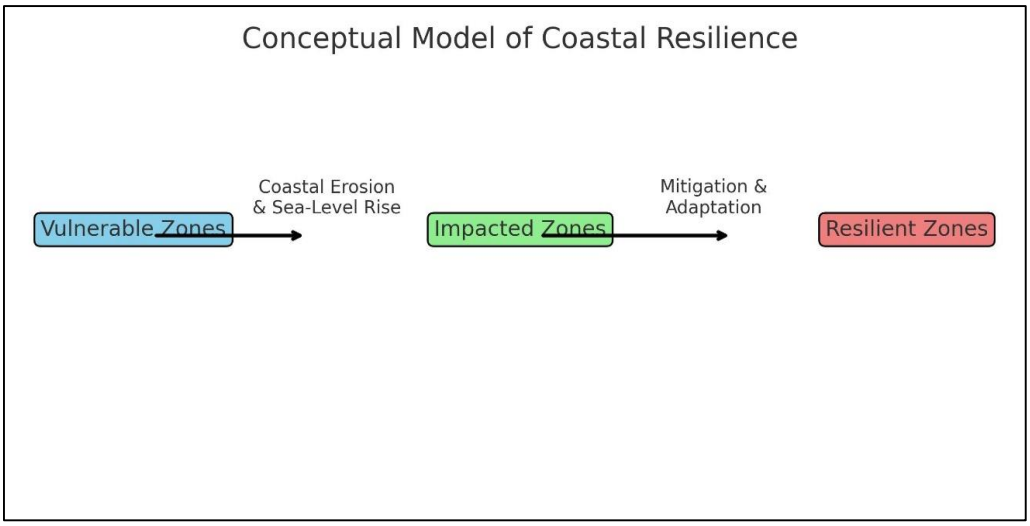


Figure 2

3. Results and Discussion

3.1 Simulation Results

The MATLAB simulations, conducted under a moderate sea-level rise scenario of 0.5 m by 2100, reveal the following key outcomes:

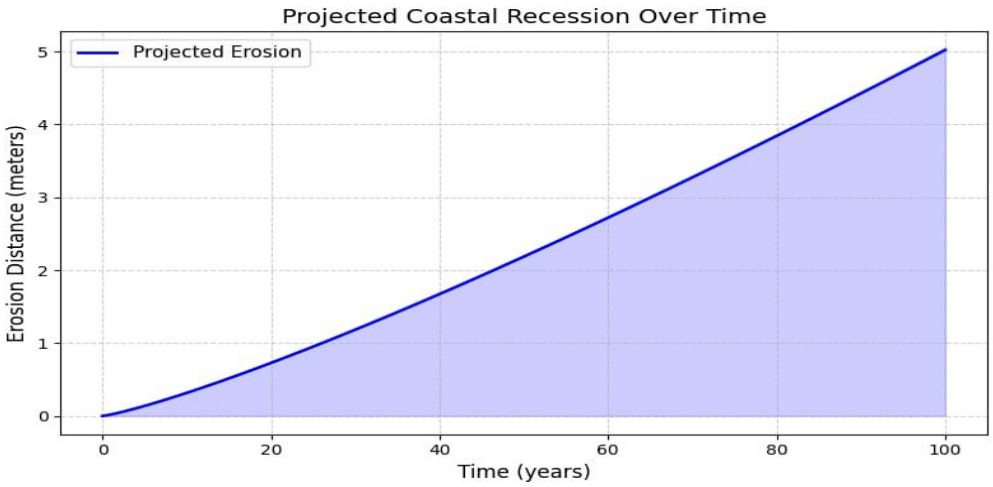


Figure 3

- **Coastal Erosion:** The rate of coastal recession increases by approximately 30–40% compared to historical data. Affected areas include the coastal zones of Thatta and Badin, where erosion threatens both natural habitats and man-made structures.
- **Infrastructure Impact:** Critical urban areas, particularly those in low-lying zones such as Thatta and nearby communities, show a projected 25% increase in damage risk. This includes roads, bridges, and public utilities.
- **Agricultural Losses:** Saltwater intrusion is predicted to extend inland by up to 20%, severely impacting the agricultural lands in rural Sindh, leading to diminished soil fertility and reduced crop yields.

3.2 Evaluation of Mitigation Strategies

The study further assesses the effectiveness of different adaptation measures:

- **Engineered Coastal Defenses:** Structures such as sea walls and levees offer immediate protection to key infrastructures. However, their long-term efficacy is contingent on regular maintenance and adaptive management.
- **Nature-Based Solutions:** The restoration of mangrove forests has proven to be highly effective, reducing erosion rates by as much as 60% in simulated scenarios. This approach also enhances biodiversity and improves water quality.
- **Integrated Adaptation Plans:** Combining both engineered solutions and ecosystem-based approaches, along with proactive community engagement, provides a robust defense mechanism against future sea-level rise. Such integrated strategies are essential for areas like Thatta and Badin, where the impacts are most severe.

3.3 Discussion of Affected Areas

The results clearly indicate that the coastal areas of Thatta, Badin, and rural parts of Sindh are among the most vulnerable to the adverse effects of sea-level rise. Urban infrastructures in these regions are under significant threat, and agricultural productivity is at risk due to saltwater intrusion. The study emphasizes that immediate intervention in these affected areas is crucial. The combination of engineered defenses with sustainable, nature-based solutions offers the best prospects for long-term resilience and sustainable development in these regions (IPCC, 2021; Malik et al., 2021).

4. Conclusion

This research highlights the critical threat posed by rising sea levels to the infrastructure and socio-economic stability of the Indus Delta. The study demonstrates that without prompt and coordinated action, affected areas such as Thatta, Badin, and rural agricultural regions in Sindh could face severe long-term impacts. An integrated approach—melding immediate engineered interventions with sustainable nature-based solutions—appears to be the most promising strategy for mitigating these risks. Enhanced monitoring, adaptive planning, and robust community engagement are recommended to ensure the long-term resilience of the delta. Future research should further refine predictive models and explore cost-effective, localized adaptation strategies tailored to the unique conditions of the Indus Delta (Khan & Hussain, 2020).

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Subject: Transportation and Infrastructure Engineering

Theme: Pavement Design, Maintenance, and Sustainability

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EFFECT OF PACKAGING MATERIAL POLYSTYRENE ON THE CONVENTIONAL PROPERTIES OF BITUMEN

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ABSTRACT: Bitumen is mostly used in road construction and can be used in asphalt as a binding material. This has a detrimental impact on its engineering performance, thus limiting its efficiency and its ability to contribute to the sustainability of the construction industry. Adding packaging material (polystyrene) to the bitumen will increase its softening, flash, and fire points efficiently and cost-effectively. Accordingly, the main purpose of this study is to recycle or reduce the quantity of waste and modify the properties of bitumen by using that waste as a modifier. For the preparation of the test, first, we ground the packaging material in powder form and then mixed that powder with 2%, 4%, 6%, and 8% by weight of bitumen. After mixing, we performed all the laboratory tests on conventional and modified bitumen. Based on the results of experiments, polystyrene impacts the bitumen positively and negatively. Further results of this study show that adding packaging material (polystyrene) significantly affects the softening, flash, and fire point properties of bitumen.

KEYWORDS: asphalt binder, bitumen modification, polystyrene, sustainable construction, waste recycling.

1. Introduction

1.1 General

Bitumen has been used in construction since ancient times, primarily as a binding material in asphalt pavement for road construction. One of its key properties is its ability to convert pervious layers into impervious ones. Derived from the distillation of crude oil, bitumen is known for its waterproofing and adhesive characteristics. During the distillation process, lighter components such as gasoline and diesel are removed, leaving behind heavier bitumen. This bitumen can then undergo further refining to improve its grade and quality [1]. In addition to being obtained from crude oil, bitumen also occurs naturally at the bottoms of ancient lakes, where prehistoric organisms have been subjected to heat and pressure over millions of years. Chemically, bitumen consists of complex hydrocarbons and contains elements such as calcium, iron, sulfur, and hydrogen. Fluctuations heavily influence the price of bitumen in crude oil prices [2]. However, despite its widespread use, bitumen has several disadvantages. It significantly impacts the environment, contributing to air pollution, particularly in hot and sunny regions. For workers, exposure to bitumen fumes can cause health issues such as

coughing, skin rashes, eye irritation, and lung problems [3]. At the same time, global waste production continues to rise, leading to ecological degradation and environmental pollution. To address these challenges, researchers are exploring ways to incorporate waste materials into bitumen to reduce costs and enhance its properties. One promising approach is the use of polystyrene; a type of waste plastic commonly found in disposable plastic cups [4]. By replacing a portion of bitumen with recycled polystyrene, this method offers a more economical and sustainable alternative while improving bitumen's performance. Unmodified bitumen is a highly viscous liquid with a tendency to become brittle at low temperatures and excessively soft at high temperatures, limiting its effectiveness over the years. Despite decades of successful use in asphalt concrete for road pavements and continuous improvements in bitumen production, mix design, and pavement design, there are still limitations to its application in road construction. This is why modifying bitumen has become a focus of research and development [5]. Modified bitumen offers significant advantages for highway and motorway construction, particularly in terms of maintenance, handling, and durability. It enhances the efficiency and comfort of road infrastructure while improving its overall performance. One promising method of modification involves incorporating polystyrene into bitumen. The addition of polystyrene alters the physical properties of bitumen, improving its softening point and reducing its brittleness. It also affects key characteristics such as penetration, making the modified bitumen more resilient and adaptable to varying temperature conditions.

1.2 Properties of Bitumen.

Bitumen possesses several key properties that make it suitable for construction and road applications. It is a highly viscous material that softens when heated and hardens upon cooling. Its physical properties include viscosity, softening point, penetration value, ductility, and specific gravity, which determine its workability and durability. Mechanically, bitumen has strong adhesive properties, ensuring effective bonding with aggregates, and exhibits both elasticity and plasticity, allowing it to withstand varying stresses. Thermally, it is sensitive to temperature changes, becoming brittle in cold conditions and soft in high heat, while its flash and fire points indicate its flammability [6]. Chemically, bitumen is composed of complex hydrocarbons, along with elements such as carbon, hydrogen, sulfur, oxygen, and nitrogen. It undergoes oxidation over time, which can reduce its flexibility. It is highly water-resistant, making it useful for waterproofing applications. Environmentally, bitumen can be recycled and modified with polymers or waste plastics to enhance performance, though it also contributes to air pollution and emits fumes that may pose health hazards [7]

1.3 Packaging Material Polystyrene.

Table 1. Properties of Packaging Material Polystyrene.

S.No	Property	Definition
01	Modifier for Bitumen	Polystyrene is used as an additive to improve bitumen performance in road construction.
02	Improved Rutting Resistance	When mixed with bitumen, polystyrene enhances resistance to deformation under heavy traffic loads.

03	Increased Stiffness	Polystyrene-modified bitumen has higher stiffness, reducing temperature-induced softening.
04	Enhanced Water Resistance	Polystyrene increases bitumen's resistance to moisture damage, improving pavement durability.
05	Improved Elasticity	Bitumen modified with polystyrene exhibits better flexibility, reducing cracking.
06	Lightweight Addition	Polystyrene does not significantly increase the weight of bitumen, maintaining ease of application.
07	Potential for Recycling	Waste polystyrene can be used in bitumen modification, promoting sustainability.
08	Reduced Crack Formation	It helps prevent cracks due to temperature fluctuations and load stress.
09	Cost-Effective Enhancement	Using polystyrene waste as a modifier can be an economical way to improve bitumen properties.

2. Materials and Methodology

2.1 Bitumen

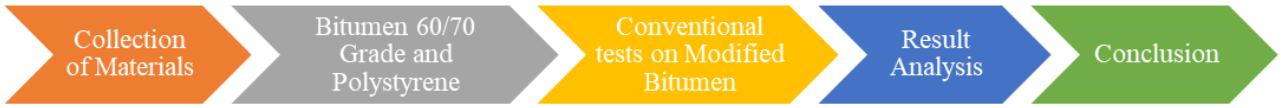
Bitumen is a dense, dark-colored hydrocarbon composite that can be found naturally or obtained through the refining of crude oil. It primarily consists of hydrocarbons, with large molecules known as asphaltenes forming its core structure. Bitumen is widely used in applications requiring a durable and waterproof material, such as road construction, roofing, and waterproofing. It also functions as an adhesive and sealant in various industrial processes and serves as a binder in asphalt concrete for road surfaces. In this study, 60/70 penetration grade bitumen is selected as the base material due to its optimal balance of hardness and flexibility, making it ideal for road construction and pavement applications.

2.2 Waste Polystyrene

Waste polystyrene includes discarded polystyrene-based products such as packaging materials, disposable containers, insulation, and other plastic items. Proper recycling and reuse are essential to minimize environmental pollution. This study focuses on expanded polystyrene (EPS) and general-purpose polystyrene (GPPS), which are widely used thermoplastics derived from styrene monomers. Polystyrene is lightweight, rigid, and commonly found in packaging, insulation, and disposable products [8]. In recent years, global polystyrene production has significantly increased, with a large portion used for packaging applications. This research investigates the effects of adding polystyrene to bitumen in 2%, 4%, 6%, and 8% proportions to evaluate its impact on penetration, softening point, ductility, and Flash and Fire point.

Figure 1-3. Waste Polystyrene Cups, Plates, and Bowls

2.3 Methodology Chart



2.4 Tests on Modified Bitumen

Testing is a vital part of bitumen production and application, ensuring it meets specific quality standards and performs as required. These tests help manufacturers and users select the appropriate bitumen grade based on its properties. The ASTM (American Society for Testing and Materials) has established a series of physical tests to assess the strength, durability, and performance of bitumen binders.

Table 2. Tests on Bitumen

S. No	Test	ASTM Standard	Description
01	Penetration value test.	ASTM D5	-Heat the bitumen sample and pour it into a standard penetration cup, then cool it to 25°C. -Place a standard needle under a 100g load for 5 seconds and measure the depth of penetration (in tenths of a mm). -A higher penetration value indicates softer bitumen, while a lower penetration suggests harder bitumen.
02	Specific gravity test.	ASTM D70	-Weigh a clean, dry pycnometer and fill it with bitumen. -Determine the weight of the pycnometer with bitumen and compare it with an equal volume of water. -Specific gravity is calculated as the ratio of the bitumen's density to water's density.
03	Ductility test.	ASTM D113	-Heat and pour the bitumen into a ductility mould, then cool it to 25°C in a water bath. -Stretch the sample at a rate of 5 cm per minute until it breaks.

			-The elongation before breaking determines the ductility of bitumen.
04	Softening point test.	ASTM D36	-Fill bitumen in two brass rings and cool it in a water bath. -Cool the water at 5°C per minute while placing steel balls on the bitumen samples. -The temperature at which the bitumen softens enough for the ball to fall 25 mm is recorded as the softening point.
05	Flash & fire point test.	ASTM D92	-Heat bitumen in an open cup at a controlled rate under standard conditions. -Apply a small test flame at regular temperature intervals to check for ignition. -The flash point is when vapors ignite momentarily, and the fire point is when they sustain combustion.

5. Results and Discussion

The results obtained from the experimental investigation on the effect of polystyrene on the conventional properties of bitumen. The results are analyzed and discussed in relation to standard bitumen properties, with a focus on penetration, softening point, ductility, specific gravity, flash point, and fire point. The optimum polystyrene replacement percentage is determined based on the overall performance of modified bitumen

Table 3. Test results of Modified Bitumen

Sr. no.	**Test**	**Percentage of Polystyrene**				
		0%	2%	4%	6%	8%
01	Penetration Value (mm)	85.2	68.87	60.5	35.2	36.53
02	Specific gravity	1.01	1.001	0.99	0.97	0.96
03	Softening Point (^{O}C)	42.33	45.3	48.33	50.4	52.3
04	Ductility Value (cm)	Doesn't break	76.43	69.13	65.47	66.63
05	Flash Point (^{O}C)	229.77	250.67	274.03	291.57	292.7
06	Fire point (^{O}C)	260.57	279.8	304.2	321.2	323.167

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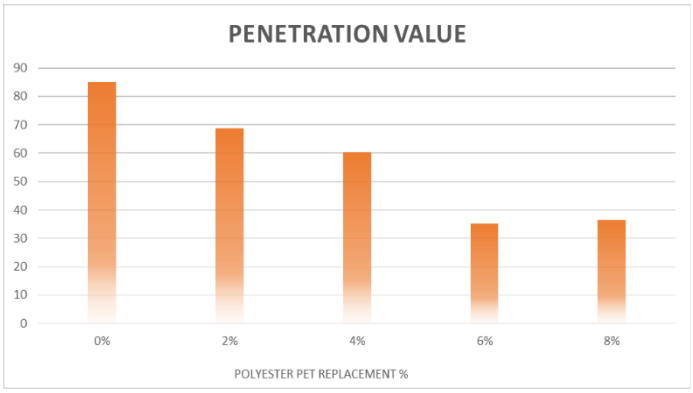
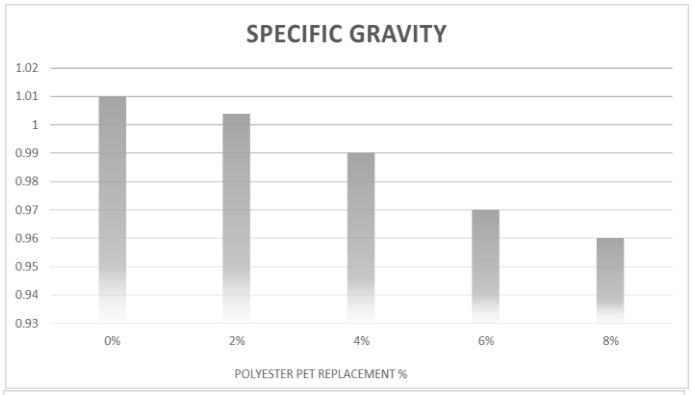
3.1 Effect of Polystyrene on Penetration Value.

enetration is a key indicator of bitumen's consistency and hardness [13]. The results show a gradual decrease in penetration values with an increase in polystyrene content. The penetration values indicate that the addition of polystyrene stiffens the bitumen, making it more resistant to deformation under loading conditions. The optimum penetration value was observed at 8% replacement, suggesting improved structural integrity. This reduction in penetration is beneficial for high-temperature environments, as it enhances the pavement's durability.



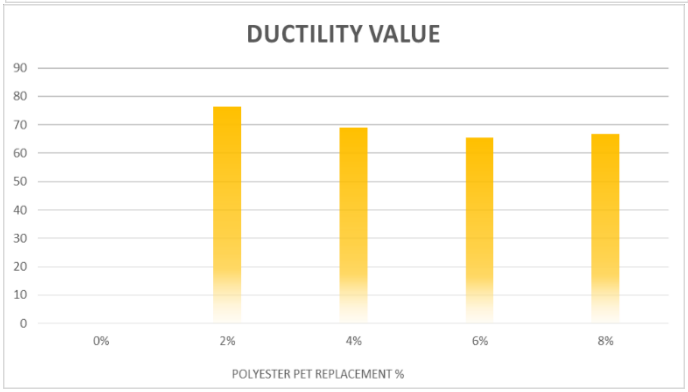
5.2 Effect of Polystyrene on Specific Gravity.

Specific gravity is a crucial parameter that affects the density and workability of bitumen [16]. The results show that the addition of polystyrene slightly alters the specific gravity of bitumen. The changes observed remain within acceptable limits, ensuring the modified bitumen retains its desired performance characteristics. Maintaining an optimal specific gravity ensures proper bonding with aggregates and improves overall pavement stability.



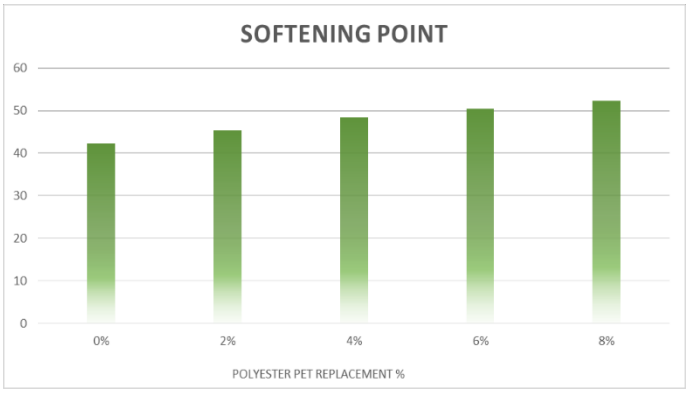
5.3 Effect of Polystyrene on Ductility Value.

Ductility is a measure of bitumen's ability to stretch before breaking [14]. The results indicate a reduction in ductility as polystyrene content increases. While high ductility is desirable for flexible pavements, the observed reduction is within acceptable limits, suggesting that the modified bitumen remains workable and can still perform adequately under varying traffic loads and temperature conditions.



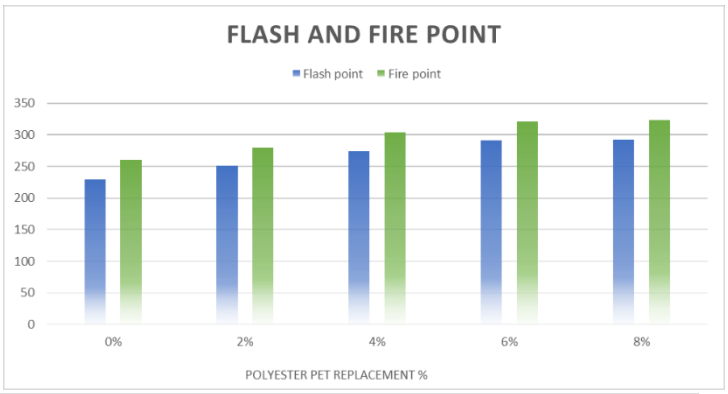
3.6 Effect of Polystyrene on Softening Point Value.

The softening point of bitumen increased with the addition of polystyrene. This trend suggests an improvement in the thermal stability of the modified bitumen, making it more resistant to high-temperature rutting. The increase in softening point is attributed to the presence of polystyrene, which enhances the stiffness of the bitumen matrix. The maximum softening point was achieved at 8% replacement, indicating enhanced heat resistance. A higher softening point ensures the bitumen remains stable under hot weather conditions, reducing the chances of road surface deformation [15].

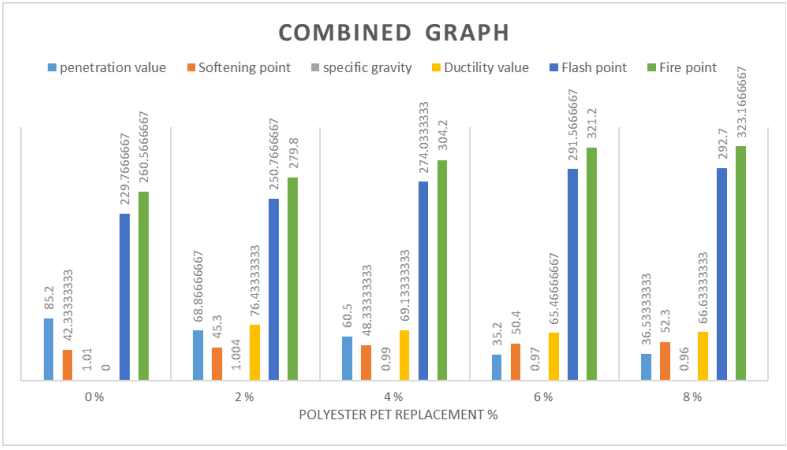


3.7 Effect of Polystyrene on Flash and Fire Point.

The flash point and fire point indicate the temperature at which bitumen emits vapors that can ignite [17], [18]. The results reveal an increase in both flash point and fire point with the addition of polystyrene. This suggests enhanced safety characteristics, as the modified bitumen exhibits improved resistance to ignition at high temperatures. A higher flash and fire point ensures that the material is safer to handle and transport under extreme conditions.



Based on the analysis of penetration, softening point, ductility, specific gravity, flash point, and fire point, the optimum replacement percentage of polystyrene in bitumen was determined to be 8%. At this level, the modified bitumen exhibited improved resistance to deformation, higher softening point, enhanced stability, and increased safety characteristics, making it suitable for high-temperature applications and heavy traffic conditions.



4. Conclusion

1. The physical properties of bitumen exhibit both increases and decreases as the proportion of polystyrene rises. While some characteristics improve, others deteriorate.
2. Specific gravity, penetration, and ductility decrease with the increasing percentage of polystyrene.

Each time the polystyrene content increases, the values of these properties decline.
3. In contrast, the softening point, flash point, and fire point increase as the polystyrene percentage rises. The highest values for these properties were observed at 8% polystyrene content.
4. A decrease in penetration value is beneficial, as lower penetration indicates harder bitumen, making it suitable for hot climates.
5. However, a reduction in ductility is a drawback, as lower ductility means decreased elasticity, increasing the likelihood of cracking.
6. This study confirms that the softening point of bitumen rises with increasing polystyrene content. A higher softening point makes bitumen more suitable for hot climate conditions.
7. Additionally, the flash and fire points of bitumen consistently increased with each trial, further demonstrating the impact of polystyrene on these properties.
8. In conclusion, incorporating polystyrene enhances certain bitumen properties, positively affecting penetration, softening point, flash point, and fire point. However, it also negatively impacts ductility.
9. The addition of polystyrene to bitumen presents a viable solution to several challenges faced by virgin or conventional bitumen today.

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FUTURE RECOMMENDATIONS

Scientific research is a name of delving into new grounds to an existing work of study and exploring new techniques which can benefit humans and technology as well. Some recommendations for the research on packaging material (polystyrene) in bitumen are discusses below.

1. Polystyrene enhance the performance of bitumen at many levels but also behaves adversely as far as some properties are concerned, further study must be carried out to examine all the properties affected by polystyrene emphatically and resentfully.

2. Different percentages like 10%, 12%, 14% etc., of polystyrene in bitumen can be experimented and examined.

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[15] “ASTM D36 – Determines the softening point of bitumen using the ring-and-ball method. It assesses the temperature at which bitumen softens under heat.”.
[16] “ASTM D70 – Measures the density and specific gravity of bitumen using a pycnometer. It is essential for quality control and material classification.”.
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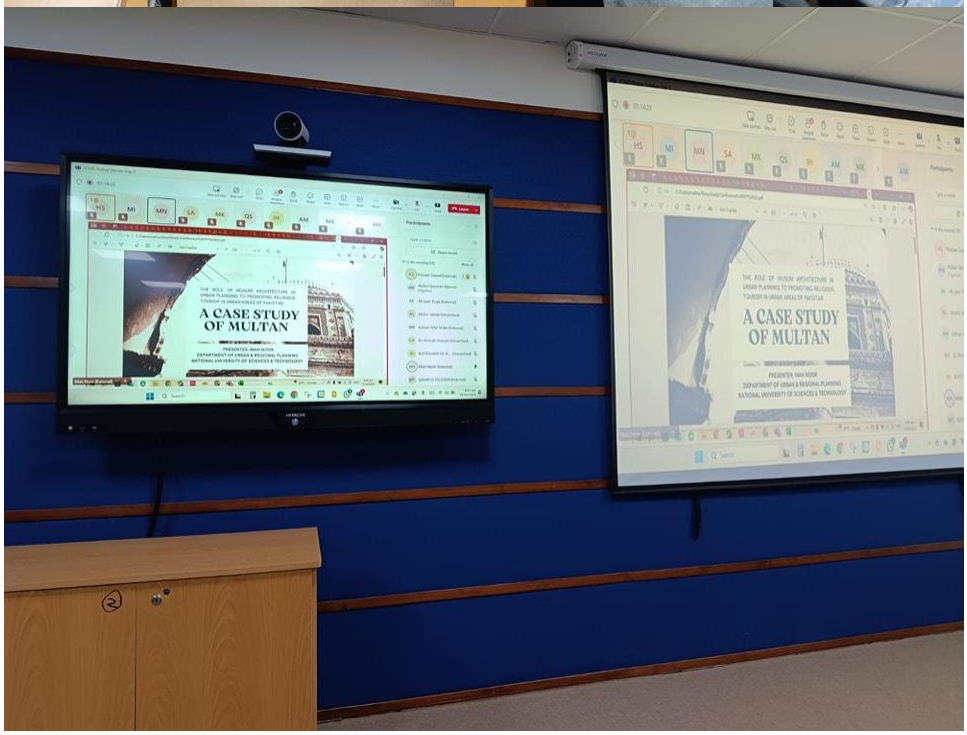
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